Proceedings of the inaugural construction management and economics 'Past, Present and Future' conference CME25, 16-18 July 2007, University of Reading, UK

Construction Management and Economics

CME 25 Conference
16-18th July 2007
University of Reading, UK

25 years of CME

CME 25 Conference Construction Management and Economics

'Past, Present and Future'

16th–18th July 2007
University of Reading, UK

Volume 1

CME 25 Conference

Proceedings of the Inaugural *Construction Management and Economics* 'Past, Present and Future' conference

Edited by Will Hughes

First published 2008

ISBN 978-0-415-46059-0 (3 vols.)

Professor Will Hughes
Head of School of Construction Management and Engineering
University of Reading
PO Box 219
Reading
RG6 6AW, UK

SCIENTIFIC COMMITTEE

Prof Ghassan Aouad, University of Salford, UK
Prof David Arditi, Illinois Institute of Technology, USA
Prof Michael Ball, University of Reading, UK
Prof Hans Björnsson, Chalmers University of Technology, Sweden
Prof Paul Bowen, University of Cape Town, South Africa
Prof Mike Bresnen, University of Leicester, UK
Prof Jan Bröchner, Chalmers University of Technology, Sweden
Ms Elisabeth Campagnac, ENPC, France
Dr John Connaughton, Davis Langdon, UK
Prof Nicola Costantino, Politecnico di Bari, Italy
Prof Andy Dainty, Loughborough University, UK
Dr Peter Edwards, RMIT University, Australia
Dr Richard Fellows, University of Hong Kong, China
Prof Martin Fischer, Stanford University, USA
Dr Sivaguru Ganesan, University of Hong Kong, China
Prof David Gann, Imperial College of Science and Technology, UK
Prof Vernon Ireland, University of Adelaide, Australia
Mr Graham Ive, University College London, UK
Prof Dave Langford, Glasgow Caledonian University, UK
Prof Peter Lansley, University of Reading, UK
Prof Heng Li, Hong Kong Polytechnic University, China
Dr John Miller, Patton Boggs, USA
Prof Ronie Navon, National Building Research Institute, Israel
Prof George Ofori, National University of Singapore, Singapore
Prof Roberto Pietroforte, Worcester Polytechnic Institute, USA
Prof John Raftery, Oxford Brookes University, UK
Dr Malik Ranasinghe, University of Moratuwa, Sri Lanka
Dr Göran Runeson, University of New South Wales, Australia
Prof Frank Schultmann, University of Siegen, Germany
Dr David Seymour, University of Birmingham, UK
Prof Amarjit Singh, University of Hawaii at Manoa, USA
Prof Miroslaw Skibniewski, University of Maryland, College Park, USA
Prof Martin Skitmore, Queensland University of Technology, Australia
Prof Philippe Thalmann, École Polytechnique Fédérale de Lausanne, Switzerland
Prof Paolo Tombesi, University of Melbourne, Australia
Prof Ben Uwakweh, University of Cincinnati, USA
Prof Shou-Qing Wang, Tsinghau University, China
Prof Graham Winch, Manchester Business School, UK
Prof Tomonari Yashiro, University of Tokyo, Japan
Prof Zhong Denghua, Tianjin University, China

Introduction

This conference was an unusual and interesting event. Celebrating 25 years of *Construction Management and Economics* provides us with an opportunity to reflect on the research that has been reported over the years, to consider where we are now, and to think about the future of academic research in this area. Hence the sub-title of this conference: "past, present and future". Looking through these papers, some things are clear. First, the range of topics considered interesting has expanded hugely since the journal was first published. Second, the research methods are also more diverse. Third, the involvement of wider groups of stakeholder is evident. There is a danger that this might lead to dilution of the field. But my instinct has always been to argue against the notion that Construction Management and Economics represents a discipline, as such. Granted, there are plenty of university departments around the world that would justify the idea of a discipline. But the vast majority of academic departments who contribute to the life of this journal carry different names to this. Indeed, the range and breadth of methodological approaches to the research reported in *Construction Management and Economics* indicates that there are several different academic disciplines being brought to bear on the construction sector. Some papers are based on economics, some on psychology and others on operational research, sociology, law, statistics, information technology, and so on. This is why I maintain that construction management is not an academic discipline, but a field of study to which a range of academic disciplines are applied.

This may be why it is so interesting to be involved in this journal. The problems to which the papers are applied develop and grow. But the broad topics of the earliest papers in the journal are still relevant today. What has changed a lot is our interpretation of the problems that confront the construction sector all over the world, and the methodological approaches to resolving them. There is a constant difficulty in dealing with topics as inherently practical as these. While the demands of the academic world are driven by the need for the rigorous application of sound methods, the demands of the practical world are quite different. It can be difficult to meet the needs of both sets of stakeholders at the same time. However, increasing numbers of postgraduate courses in our area result in larger numbers of practitioners with a deeper appreciation of what research is all about, and how to interpret and apply the lessons from research. It also seems that there are contributions coming not just from construction-related university departments, but also from departments with identifiable methodological traditions of their own. I like to think that our authors can publish in journals beyond the construction-related areas, to disseminate their theoretical insights into other disciplines, and to contribute to the strength of this journal by citing our articles in more mono-disciplinary journals. This would contribute to the future of the journal in a very strong and developmental way. The greatest danger we face is in excessive self-citation, i.e. referring only to sources within the CM&E literature or, worse, referring only to other articles in the same journal. The only way to ensure a strong and influential position for journals and university departments like ours is to be sure that our work is informing other academic disciplines. This is what I would see as the future, our logical next step. If, as a community of researchers, we are not producing papers that challenge and inform the fundamentals of research methods and analytical processes, then no matter how practically relevant our output is to the industry, it will remain derivative and secondary, based on the methodological insights of others. The balancing act between methodological rigour and practical relevance is a difficult one, but not, of course, a balance that has to be struck in every single paper.

Turning to the conference, we have published 168 papers in this conference from 311 abstracts that were submitted in response to the call for papers. Of these, ten were rejected immediately as out of scope and 301 papers were invited, with comments from the abstract review, often making suggestions about how the paper might be focused. By the cut-off date, this resulted in 181 papers being submitted to the conference, of which 168 were finally accepted and published. All of these papers were reviewed by the Scientific Committee, supplemented by other authors from the conference, with at least two referees per paper. The corresponding authors represent 39 countries, which is a tremendously wide geographical spread. In organizing the schedule for the three days, I was presented with the usual problem faced by conference organizers of trying to fit all the papers in, at the same time as making this a meaningful experience for the participants. As well as the usual parallel sessions, I wanted to be sure that there was going to be good opportunities for discussion, and a new approach was tried. Associated with each of the four keynote addresses, I selected 5 papers from among those already accepted, looking for resonances with a keynote. I invited those authors to take part in a plenary session where they would make a two-minute bare bones presentation of their work (with no slides), one after the other. Thus, for each session of the conference, we started with a keynote, immediately followed by five very short presentations, and then a long discussion period picking up the themes of the keynote and the other presentations to tease out an interesting dialogue between panel members and audience. We still had the usual parallel sessions after these plenary sessions, but I felt that these helped to ensure that there was plenty to talk about, and it enabled those whose work was selected for the plenary session to get a much better engagement with a larger audience than might otherwise have been the case. I think that it is important to keep developing our approach to conferences and meetings, as otherwise there is a danger that it all becomes a bit too formulaic.

The origins of the journal may not be known to everyone: *Construction Management and Economics* was established in 1982 by Philip Read who worked for a publishing company called E & F N Spon, a company that specialized in construction books and well-known for its price books. Representing a publisher that specialized in construction, Philip Read made it his business to be aware of who was doing what in this field. So he approached Professor John Bennett at the University of Reading to be the editor of this new journal, and the first issue was published in 1983. Under John's editorship, the journal grew from about 240 pages per year to roughly double that size. In 1992, Ranko Bon and I took over as editors. This partnership lasted for 12 years until Ranko's retirement. While the journal continued to grow under my sole editorship, it became clear that the work was too much for one editor, so this year, I invited Andy Dainty and Frank Schultmann to join the editorial team, and between us we now preside over the production of about 1300 pages per year. The growth in the scale of the journal is clear from Figure 1, which shows how many pages have been published in each volume since the journal started.

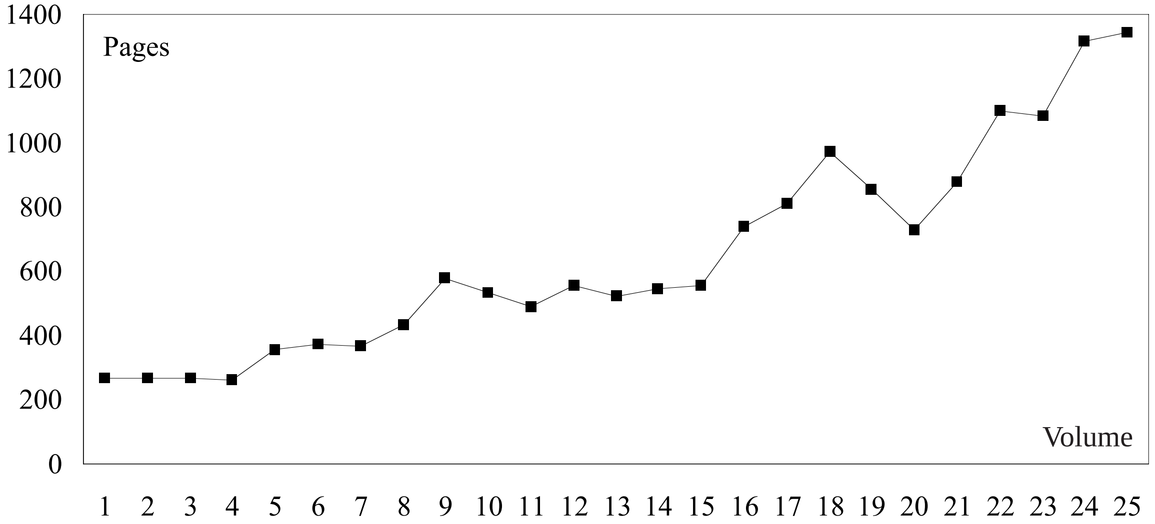


Figure 1: Numbers of pages per volume

The growth of the journal is undoubtedly linked to the growth in academic departments around the world. As academics in these departments develop their research profiles and seek outlets for their work, *Construction Management and Economics* is one of the main journals to which their work is submitted. Figure 2 shows the inexorable growth in the flow of papers into the journal, as well as the changes in numbers of papers accepted/rejected. The rejection rate appears fairly constant, hovering around 50%

One question that often arises when I show Figure 2 to various audiences is about the impact of the occasional Research Assessment Exercises (RAE) in the UK. Observers often assume that there must be a peak in submissions immediately prior to these. The lowest line in Figure 2 shows that number of papers received from UK authors

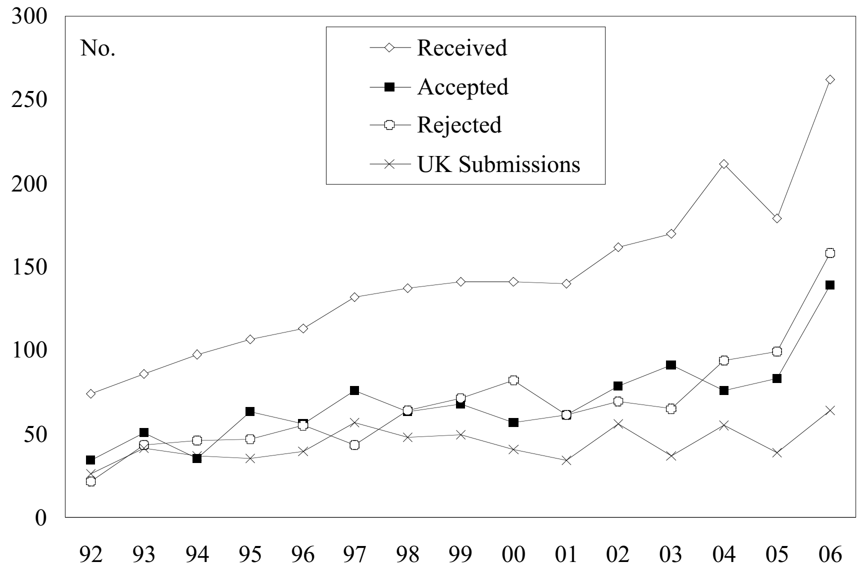


Figure 2: Annual copy flow

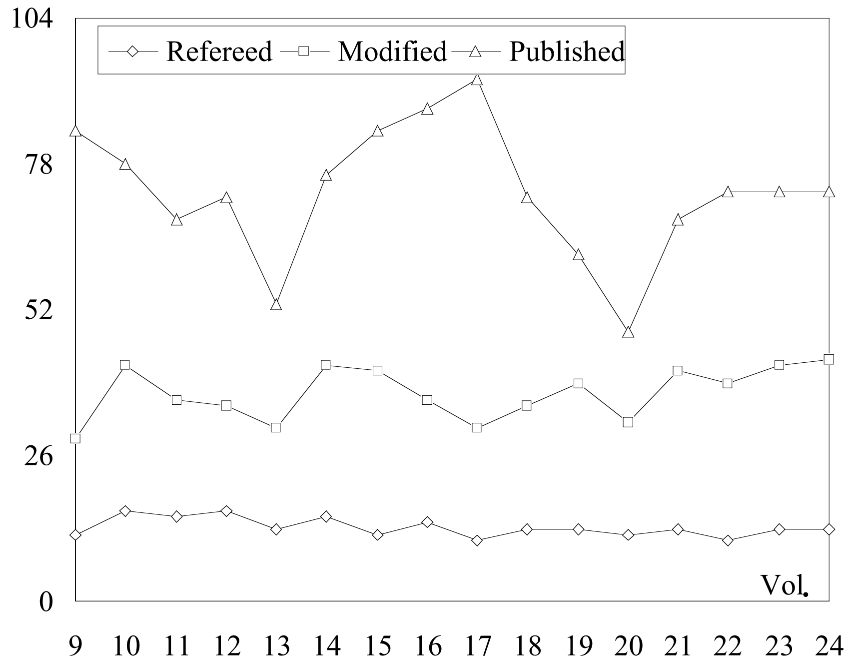


Figure 3: Performance by volume (weeks)

each year. While there is clearly a surge in 2006 (from 39 to 64) there is no similar surge immediately prior to the RAE exercises in 1996 and 2001. Moreover, the surge in submission from UK authors coincides with a surge from all authors, generally. These statistics show that UK authors are not unduly influenced into last minute submissions to this journal, an observation which runs contrary to popular belief, but may be somewhat reassuring for those who feel that the RAE process brings about publication for the sake of it. A more interesting statistic from Figure 2 is the relative constancy of copy flow from the UK, hovering around 50 papers per year, plus or minus about 10. In other words, the intense growth in the size of the journal is accounted for almost exclusively by the international scene.

One important aspect that we review every time we are considering the performance of the journal is the time it takes for papers to pass through the publication process. Figure 3 shows the average number of weeks from date of first submission to each of three points in the process: time to return referee reports after first round of refereeing, time to acceptance (including subsequent rounds of refereeing) and time to publication. The first one of these is primarily under the control of the editorial office. Despite asking referees to turn their reports around in two weeks, and despite being very diligent about sending reminders, it appears almost impossible to get this much below 13 weeks, give or take a couple of weeks. One of the reasons for this is the number of people who either fail to respond, or who let us know that they simply cannot complete the task at the moment, because of their other commitments. Clearly, non-responses slow the process a lot more than negative responses. But the consequence is that we have to invite at least eight referees to get four reports, often inviting more than 20 referees, in order to get the four reports we seek. It is the discovery of four willing and able referees that occupies most of the time in getting the papers reviewed. The distance between the first line and the second line on the graph is primarily the responsibility of authors. If their papers are well-written and

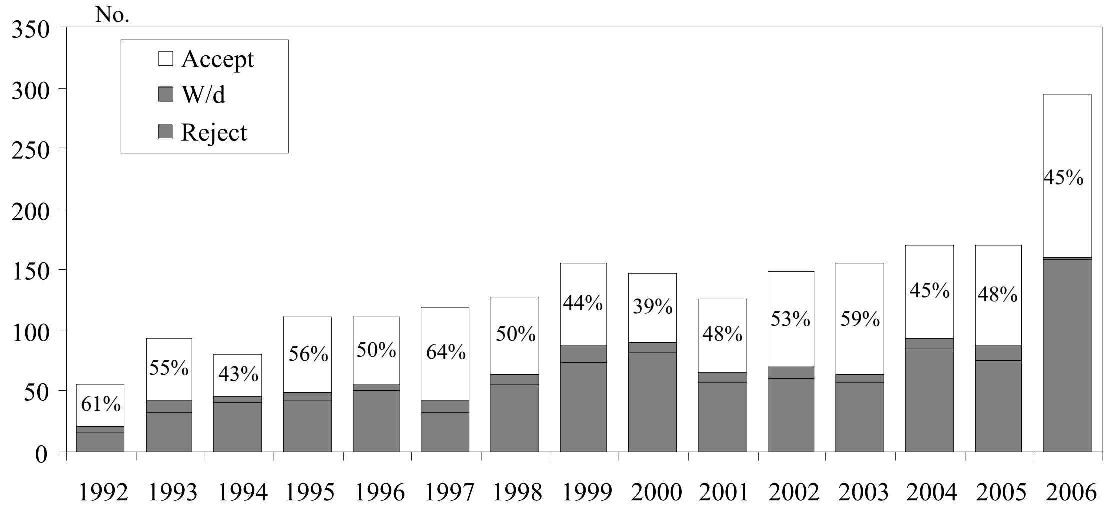


Figure 4: Annual acceptance rates

clear, reporting the results of interesting and useful research, then there will be few revisions, and little need for repeated iterations of the refereeing process. The average time spent in this phase for published papers is around six months. The distance between the second and third lines is largely the responsibility of the publisher, and indicates the length of the queue of papers that have been accepted and await publication. For the last few years this has been fairly stable at around 30 weeks. The whole process is taking 73 weeks, and this has been exactly the same for three years in a row. Relative to others, this is a good record for an academic, refereed journal.

The annual acceptance rates, as shown in Figure 4, are superimposed on the absolute number of papers accepted, withdrawn and rejected. This rate is not a target, but simply a result of the editors' interpretation of referees' reports. It is fairly constant

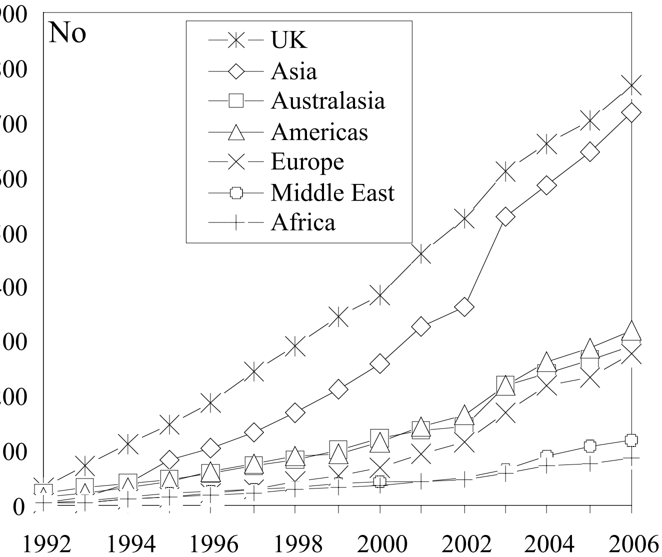


Figure 5: Origin of papers (cumulative)

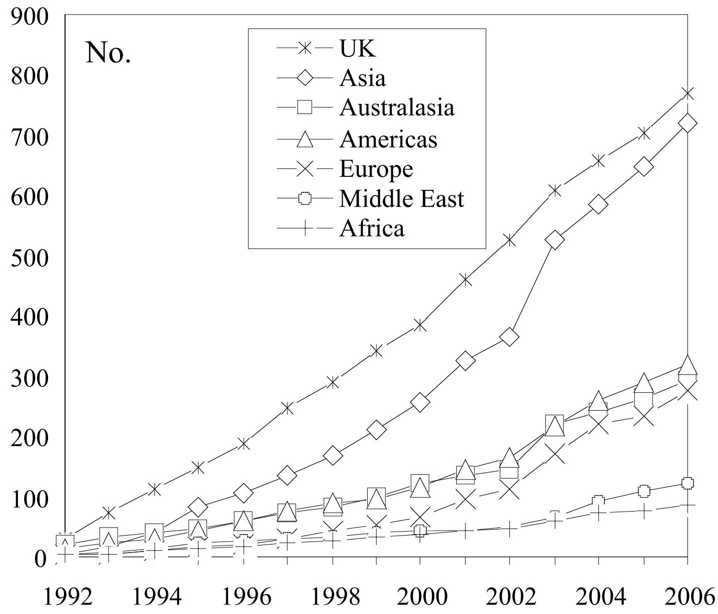


Figure 6: Origin of referees used each year

despite big changes in the numbers of papers dealt with each year.

The final category of statistics routinely produced for the journal are those regarding the origin of papers and referees. Figure 5 shows the cumulative picture of where papers are coming from since 1992. The majority of papers are still from the UK, although the cumulative data shows that the rate of growth in regions like Asia and the Americas, in particular has shown surges in recent years. As the top two lines converge, we will be continuing to see an increasing proportion of papers from outside the UK, as confirmed in Figure 2. There are clearly many diverse and inter-related reasons for the regional balance in terms of where papers are being submitted from. For most parts of Europe other than UK, for example, there is first a language barrier, and second a difference in the way that academic cases for promotion are dealt with. It is not standard practice in all countries for journal papers to play a major role in promotion cases. We are likely to see more papers from those countries where promotion is linked to publication. The huge growth of the construction sector in places like China, and the consequential growth of research and education to support it, would account for the surge in papers from that part of the world. But the large size of the USA market is not reflected in papers to this journal, perhaps because there are several well-established American journals to which American authors would turn first, before considering journals from other countries.

Finally, Figure 6 shows which regions referees are drawn from each year. This graph is not cumulative, and shows that our pool of referees is growing as rapidly as the number of papers submitted. This is bound to be the case, given that all authors are immediately entered into the referee pool. But given the difficulty of finding referees with the time to actually review papers, we are constantly on the look out for new people to add to the database. One way of providing exposure for the journal in places where it may not be well known is to invite academics from such places to review papers. This is achieved either through existing contacts making recommendations to us, or sometimes just browsing university web pages from places with appropriate academic departments, looking for research-active academics who could fulfil this role.

The statistical review of the performance of the journal provides the context for thinking about our strategy. Clearly, there are perennial questions about regional and topical coverage, quality of papers, presence in citation indexes, role of the editorial board members, and so on. These issues are the things that are regularly dealt with in our annual editorial board meetings. Although we can bring some influence to bear on the spread of papers by, for example, carefully selecting topics and guest editors for special issues, many of these characteristics are emergent, representing where the field is, rather than where the editorial team things it ought to be. We think this is a great strength of this journal. For the future, what we would like to do is to help authors in this field to have more of an influence on academic life in general, not just in construction-related departments. We shall be seeking to extend the citation indexes in which the journal's papers are listed, to help with identifiable impact factors, which seem to be developing in their importance in many countries. We will be encouraging authors to cite definitive sources from outside the journal itself, and continuing to bend every effort to make the papers in this journal the best quality that we can achieve. In this, we need the support of every author and referee in our research community – a level of support that has been constant and reliable since the journal started.

To conclude, I would like to thank the authors, referees, publishers and conference organizers for their tireless support for this excellent journal. And here's to another 25 years of a stimulating and influential journal! I hope you enjoy these conference papers.

Professor Will Hughes
CME 25 Conference Chair
Editor-in Chief, Construction Management and Economics

CONTENTS

INDUSTRY DEVELOPMENT

MILLENNIUM DEVELOPMENT GOALS AND CONSTRUCTION: A RESEARCH AGENDA

George Ofori[1]

Department of Building, National University of Singapore, 4 Architecture Drive, Singapore 117566

The Millennium Development Goals (MDGs) were set in a charter signed by the world's leaders in 2000 with the aim of attaining the sustainable development of the poorer countries and improving the quality of life of their peoples. Specific targets were agreed, to be achieved by 2015, including: eradication of hunger and poverty; achievement of universal primary education; reduction of child mortality; improvement of maternal health; and combating HIV/AIDS, malaria and other fatal diseases. The charter highlights the need for a global partnership for development. The MDGs have guided the work of international organizations such as the World Bank and various United Nations agencies. The construction industry can contribute to the attainment of the MDGs. A review of the literature shows that progress towards attaining the millennium goals has been slow although there are some encouraging results. Poor performance of the construction industry is a contributing factor to the lack of progress. Research is required to formulate initiatives which can be taken to enable the industry to make its due contribution.

Keywords: construction, developing countries, global partnership performance targets.

MILLENIUM DECLARATION

In a summit meeting in New York on 6–8 September 2000 attended by almost 150 heads of state, member countries of the United Nations (UN) adopted the Millennium Declaration. It reaffirmed the commitments of the members to the UN charter, and outlined 'certain fundamental values … essential to international relations in the twenty-first century' (UN 2000), including: freedom, equality, solidarity, tolerance, respect for nature and shared responsibility. It set out the following objectives 'to translate these shared values into actions': (1) peace, security and disarmament; (2) development and poverty eradication; (3) protecting our common environment; (4) human rights, democracy and good governance; (5) protecting the vulnerable; (6) meeting the special needs of Africa; and (7) strengthening the United Nations. The following clauses (UN 2000: section iii, paras 19 and 20), under the objective of 'development and poverty eradication' state targets which have been summarized into the Millennium Development Goals (MDGs) shown in Table 1.

19. We resolve further:

- To halve, by the year 2015, the proportion of the world's people whose income is less than one dollar a day and the proportion of people who

[1] bdghead@nus.edu.sg

suffer from hunger and, by the same date, to halve the proportion of people who are unable to reach or to afford safe drinking water.

- To ensure that, by the same date, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling and that girls and boys will have equal access to all levels of education.
- By the same date, to have reduced maternal mortality by three-quarters, and under-five child mortality by two-thirds, of their current levels.
- To have, by then, halted, and begun to reverse the spread of HIV/AIDS, the scourge of the malaria and other major diseases that afflict humanity.
- To provide special assistance to children orphaned by HIV/AIDS.
- By 2020, to have achieved a significant improvement in the lives of at least 100 million slum dwellers as proposed in the 'Cities Without Slums' initiative.'

20. We also resolve:

- To promote gender equality and the empowerment of women as effective ways to combat poverty, hunger and disease and to stimulate development that is truly sustainable.
- To develop and implement strategies that give young people everywhere a real chance to find decent and productive work.
- To encourage the pharmaceutical industry to make essential drugs more widely available and affordable by all who need them in developing countries.
- To develop strong partnerships with the private sector and with civil society organizations in pursuit of development and poverty eradication.
- To ensure that the benefits of new technologies, especially information and communication technologies … are available to all.'

MILLENNIUM DEVELOPMENT GOALS

In summary, the MDGs, to be achieved by 2015, are:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.

7. Ensure environmental sustainability.
8. Develop a global partnership for development.

The eight MDGs have been translated into 18 specific targets, and 48 indicators have been developed for monitoring progress in achieving them (www.developmentgoals.org). It is estimated that, to attain the MDGs, developing countries must grow by 7–8% per annum (World Bank 2004), and that US$50 billion per annum in additional external funds would be required. Official aid flows were projected to rise from US$69 billion in 2003 to US$135 billion in 2006, and then to US$195 billion by 2015 (Millennium Project 2005).

The literature indicates that different sets of global development targets had been set out in the 1990s (Fay *et al*. 2005). The governments of 189 countries and many organizations have committed themselves to a global partnership to achieve the MDGs. The goals have formed the basis of policy formulation and implementation in developing countries, as well as by multilateral organizations such as UN agencies, the World Bank (2006b), regional development banks (ADB 2006), and various non-governmental organizations.

Many major international programmes have been launched. For example, the World Bank's Africa Action Plan of 2005 (www.worldbank.org/afr/aap) focused on achieving development results in good governance, closing the infrastructure gap, building capable states, and more equitable distribution of the benefits of development. There have been commitments to provide more additional resources. At the G8 leaders' summit in 2005, the world's eight richest countries pledged to double development aid to Africa from US$25 billion in 2004 to US$50 billion per year by 2010. They also committed themselves to deepen debt relief especially for countries with sound financial management and a commitment to poverty reduction. However, progress here has been slow.

The private sector has also played a role. For example, with respect to the MDGs, the World Business Council for Sustainable Development (WBCSD) (2005) seeks to: (1) learn by sharing – deliver tools and guides that advance understanding of development challenges and enable all sectors to address them; (2) advocate the business contribution – help business to work with all stakeholders to build synergies among programmes; and (3) learn by doing – demonstrate success through pilot investments and exploit synergies across sectors. The WBCSD has the following 'workstreams' in this area: (1) sustainable production and consumption; (2) SMEs as business partners – strengthening local supply chains, building capacity for SMEs; capital; and (3) monitoring and evaluation of the socio-economic impact of businesses.

MDGS IN THE LITERATURE

There is much discussion in the literature on the MDGs, and the ways and means of achieving them. Fay *et al*. (2005) note that some observers believe that since improvements in most indicators of development are highly co-related with increases in per capita income, MDGs 2 to 8 are superfluous as long as the first goal is tackled. However, studies have found relationships among many of the MDGs. For example, Abu-Ghaida and Klasen (2004) note that many empirical studies have found that gender equity in education promotes economic growth, and reduces fertility, child mortality and under-nutrition. They estimated that countries which failed to attain gender equity by 2005 would suffer 0.1 to 0.3 percentage points lower per capita growth rates, and by 2015, an average of 15 per 1000 higher rates of under-five mortality, and 2.5 percentage points higher prevalence of underweight children under five.

Maxwell (2003) points out that the MDGs might encourage oversimplified interventions emphasizing social indicators at the expense of economic growth. Clemens *et al*. (2007) find fault with the way the MDGs (most of which they consider as overreaching) were set, and assert that they are impossible to meet. They note that focus on the MDGs (which stress not successes, but what remains to be done) encourages unproductive debate on where the fault for the lack of progress lies, and undermines partnership between rich and poor. Clemens *et al*. (2007: 747) observe that indicating that the MDGs can be met merely with increased resources 'contributes to the illusion that the goals are attainable for all countries'. They suggest that the specific MDG targets 'have set up many countries for unavoidable "failure"' (p. 747), even as they pursue good policies and make progress on some development indicators. Moreover, some countries may be distracted from much needed reforms. The Independent Evaluation Group (IEG) of the World Bank (2006) notes that achieving high quality development results takes time, but pressure to show results can divert attention from the quality of results. For example, efforts to attain the MDG of ensuring universal completion of primary education in 2015 have led to efforts to increase enrolments, often at the expense of the attention to learning outcomes. In Uganda, there are now 94 children per classroom, and three children share a textbook, whereas in Ghana, the development programme in the education sector combined policy reforms with the provision of school buildings and teaching materials.

White and Black (2004) note that the MDGs would not be effective as accountability for failing to meet them is diffuse. Clemens *et al*. (2007) suggest that future development goals should: (1) be country-specific and flexible; (2) take historical performance into account; (3) focus more on intermediate targets than outcomes; and (4) be considered benchmarks rather than goals which are technically feasible with sufficient funds alone.

There have been many studies on progress towards achieving the MDGs. Sahn and Stifel (2002) assess progress on six of the MDGs relating to living standards in Africa, and paint a discouraging picture. Baulch (2006) found that most donors are not distributing their aid in a way that is consistent with the MDGs, i.e., they do not direct large shares of their concessionary aid flows to the poorest and most deprived countries. There have also been studies, and some debate, on the effects of possible interventions. Fay *et al*. (2005) found that better access to infrastructure (piped water, sanitation and electricity) has a large and statistically significant effect in reducing infant and child mortality and incidence of malnutrition. Ravallion (2007) disputes these findings, questioning the estimating methods adopted. He also concluded that (contrary to the findings of Fay *et al*.) there was complementarity between basic infrastructure and health care, whereby at sufficiently high levels of initial health care, improvements in basic infrastructure reduce infant and child mortality and the incidence of malnutrition. In response, Fay *et al*. (2007: 930) highlight the complexity of the situation and call for more research. They note that:

> the analysis provided by Ravallion suggests that additional work is needed to properly assess the impact of access to infrastructure, … health care, and schooling on child health. Concluding that infrastructure and health care have no impact, as one might be led to believe in the preferred specification of

> Ravallion, would contradict both common sense and other evidence… The solution to the puzzle will involve better data sets, so that with proper modeling … more robust results can be obtained …

CURRENT RESULTS

The World Bank (2006a) indicates that joint efforts to reach the MDGs are falling short. The world is on target to reduce extreme poverty by half by 2015. However, performance varies among regions. The greatest progress has been made in Asia, especially in China and India. In China, between 1990 and 2005, the number of people living on less than US$2 a day fell by over 400 million. In India, the level of poverty fell from 36% in 1993–94 to 26% in 1999–2000. In particular, sub-Saharan Africa, as a region, is unlikely to meet the goal (World Bank 2006b). The results are also mixed in terms of the other goals: less than 80% of countries are on target to meet the child mortality goal.

Progress has been made in some countries in Africa. The World Bank (2007b) reports that 13 sub-Saharan African countries have attained middle-income status, with another five on course. More than one-third of Africans now live in the 15 countries that have grown by 5.3% per annum for over a decade. Gross primary school enrolments in Africa reached 96% in 2004. Africa is considered the world's third fastest region in the pace of reforms to reduce the time and cost needed to start a business (World Bank and IFC 2006). However, the World Bank (2007b) reports that more than 314 million Africans – nearly twice as many as in 1981 – live on less than $1 a day. Thirty-four of the world's 48 poorest countries, and 24 of the 32 countries ranked lowest on the United Nations Development Programme's Human Development Index, are in Africa. Most African countries remain high-cost, high-risk places to do business (World Bank and IFC 2006). Africa receives only about 10% of foreign direct investment to developing countries. In 2006, many African countries' exports expanded by about 8% owing to higher prices for resources, but this was not enough to offset the continuing decline in the continent's share of world trade.

The Latin America and Caribbean region grew by 6.0%, 4.5% and 5.0% in 2004, 2005 and 2006 respectively because of higher export revenues and volumes resulting from high commodity prices and world growth (World Bank 2007c). The countries have achieved significant progress in education. In Grenada, repetition rates in secondary schools have been reduced from 11.6% to 1.3% between 1994–95 and 2000–01. In Mexico, a project helped increase completion rates in primary education from 66% in 1994–95 to 80% in 2000–01 in disadvantaged communities in 14 of Mexico's poorest states. However, the region continues to face the related development challenges of increasing growth, while reducing poverty and inequality – some 106 million people (nearly 21% of the population) live on less than $2 a day.

CONSTRUCTION AND MDGS

The role of construction in development, and hence in efforts to meet the MDGs is evident in three main ways (Hillebrandt 2000; Ofori 2000). First, buildings and items of infrastructure are inputs for economic and social activity, leading to increased incomes and national development. Second, construction work stimulates activities in other sectors of the economy from which the industry obtains its inputs, such as manufacturing. This contributes to economic growth and development. Finally, construction provides employment opportunities. This can make its workers effective consumers in the economy, further stimulating activities in other sectors. On the other hand, a growing economy, expanding related sectors, and higher employment, individually and together, lead to increased demand for construction (Wells 1986). Thus, there is a cyclic relationship between construction and the attainment of the MDGs. Indeed, Matthews *et al*. (2003) outline the benefits construction firms gain by improving their social performance: they are competitive when tendering for certain projects by demonstrating their ability to meet clients' social performance objectives; they enhance their brand reputation; and they reduce project risks and overruns. In Table 1, the contribution which construction can make towards the attainment of the MDGs is presented, together with Indicators for measuring the progress which the industry makes in this process.

From the above discussion, the construction process can be a bottleneck in the effort to realize the MDGs. Therefore, the capacity of the industry in the developing countries should be enhanced to enable it to deliver a higher volume of output to meet the increased demand as initiatives to realize the MDGs are implemented. The capability of the industries should also be enhanced to enable cost effectiveness and time efficiency on projects. Greater attention to cost performance would mean that more construction would be provided per unit of money; would enable national budgets to cover greater volumes of construction; and widen the pool of clients who can express effective demand for constructed items. Time efficiency would help to remove the constraints which buildings and infrastructure might pose to the process of national development. Quality and durability should also be addressed to provide further elements of value for money.

The literature has long highlighted the employment generation potential of construction (Hillebrandt 2006). This potential can be most effectively realized through the adoption of appropriate procurement approaches and technologies. Greater attention should be paid to technology assessment and selection in construction (see, for example, Howe and Bantje 1995; ILO 2003). Studies have also found that construction sites and their workers contribute to the spread of mosquito-borne diseases (Vijayan and Neo 2007) and HIV/AIDS (Meintjes *et al*. 2007). Thus, working conditions on sites should be improved to reduce the spread of diseases among the industry's workers and the community.

Partnerships between the construction industry and its stakeholders should be established to ensure the effectiveness of the industry's contribution to the attainment of the MDGs. The stakeholders, and their interests and aspirations in relation to construction should be identified; their expectations and views should be ascertained; and the best form of partnership with each stakeholder should be found. Construction firms should be MDG compliant in their operations. They should seek new ways of doing business that lead to mutual gain for themselves and their stakeholders, for example, by adopting the above approaches, in effect, widening the client base and enhancing the people's well-being.

One of the most direct ways in which construction influences the attainment of the MDGs, infrastructure provision, is now considered.

INFRASTRUCTURE DEVELOPMENT AND MDGS

The literature highlights the role of infrastructure in economic growth and development (Han and Ofori (2001) provide a useful review). Fedderke *et al*. (2006) analysed data for South Africa from 1875 to 2001 and found that investment in infrastructure leads to long-term economic growth both directly and indirectly, the latter by increasing the marginal productivity of capital. The World Bank (2007a) notes that improving infrastructure in developing countries is a key factor in reducing poverty and increasing growth; it is vital to the achievement of the MDGs as it improves access to water and electricity, as well as schools, hospitals and markets. The World Bank (2007a) observes that if Africa had attained infrastructure growth rates comparable to those in East Asia in the 1980s to 1990s, it could have achieved annual growth rates about 1.3% higher. Similarly, it is estimated that the lack of investment in infrastructure in the 1990s reduced long-term growth in the Latin America and Caribbean region by 1–3 percentage points, and hindered the region's ability to compete with the dynamic Asian economies (World Bank 2007d). In India, the Minister of Finance, P. Chidambaram, expressed concern over an 'intractable' problem of 'deficit infrastructure', considered to be a severe constraint on the country's development effort; the government has made infrastructure its priority (*The Hindu* 2005).

There are many recent examples of the economic and social stimulus from investments in infrastructure. Two World Bank (2007d) projects in Peru rehabilitated 13 000km of rural roads, reducing travel time by an average of 68%; and increasing school enrolment by 8% and visits to health centres by 55%. In Peru, the rehabilitation of some 11 000km of rural roads in the Sierra countryside improved access to markets for 3 million poor people and created jobs in 410 local road maintenance enterprises. In Morocco, the construction of an all-weather road in rural communities increased girls' primary school attendance from 28% to 68%.

ACTION IN ADDRESSING MDG IN CONSTRUCTION

Action has been taken to use construction to realize the MDGs, especially that on poverty reduction. The International Labour Office (ILO) has had a programme to develop and promote labour-based construction, focusing on roads, since the 1970s. Its work has included the development of design and specifications, technology, procurement methods and capacity building (training and SME development) (see, for example, ILO (2003)). Some professional institutions are relating the MDGs to their efforts in construction industry development. Engineers Against Poverty (2006) sought to identify opportunities to improve the delivery of social development objectives by modifying the way in which public infrastructure projects are procured. It suggested: (1) project identification should be in line with national, local or sector plans and/or based on public consultation; (2) the whole life cycle of the project should be considered during planning and design, and a maintenance strategy developed; (3) social objectives should be clearly identified at the planning stage and incorporated into design; (4) funds should be set aside in the budget for the realization of social objectives; (5) an appropriate procurement approach to deliver the specified social objectives should be chosen; (6) the bidders' social performance and capacity to deliver social obligations should be considered; (7) contractual obligations

Table 1: The Millennium Development Goals and role of construction (source of MDGs: United Nations www.un.org.org/milleniumgoals/images/mdgs_01.gif)

Millennium Development Goal	Contribution of construction	Indicators for construction
Goal 1: Eradicate extreme poverty and hunger * Reduce by half the proportion of people living on less than a dollar a day * Reduce by half the proportion of people who suffer from hunger	* Effective and efficient production of buildings and infrastructure * Maximum linkages of construction to other sectors of national economy to create stimulus * Generation of employment opportunities through appropriate choice of technology and procurement * Continuous development of industry	* Performance of industry, company or project on key indicators, such as time, cost, quality, safety * Features of construction in national input–output tables * Number of jobs created, average wages * Average corporate profits; profits on projects
Goal 2: Achieve universal primary education * Ensure that all boys and girls complete a full course of primary education	* Design and construction of suitable school buildings (in local economic, climatic contexts) * Contribution to economic growth and national development to create jobs for graduates	* Estimate of total capacity of national industry, and that of the firm
Goal 3: Promote gender equality and empower women * Eliminate gender disparity in primary and secondary education preferably by 2005 and in at all levels by 2015	* Creation of job opportunities for women and youth (Goal 8) at all levels in construction, with close attention to working conditions on sites, remuneration and career progression	* Proportion of females in workforce of industry, company, project, at different levels * Average remuneration of employees of different genders
Goal 4: Reduce child mortality * Reduce by two-thirds, the mortality rate among children under five *Goal 5: Improve maternal health* * Reduce by three-quarters, the maternal mortality ratio	* Construction of hospitals and infrastructure * Provision of job opportunities to generate income	* Same indicators as for MDGs 1 and 2
Goal 6: Combat HIV/AIDS, malaria and other diseases * Halt and begin to reverse the spread of HIV/AIDS * Halt and begin to reverse the incidence of malaria and other major diseases	* Effective site management to avoid health hazards * Initiatives to avoid spread of HIV/AIDS by construction workers (through education)	* Industry, company, project performance on health and safety * Industry and company policies and programmes on HIV/AIDS
Goal 7: Ensure environmental sustainability * Integrate the principles of sustainable development into country policies and programmes; reverse the loss of environmental resources * Reduce by half the proportion of people without sustainable access to safe drinking water * Achieve significant improvement in the lives of at least 100 million slum dwellers by 2020	* Sustainable construction – cradle to grave considerations of all aspects of construction * Effective management of completed buildings and infrastructure	* Industry, company, project performance on sustainable construction – waste generation * Average scores in environmental assessment of buildings * Energy performance of various types of buildings
Goal 8: Develop a global partnership for development * Develop further an open trading and financial system that is rule-based, predictable and non-discriminatory, includes a commitment to good governance, development, and poverty reduction—both nationally and internationally * Address the least developed countries' special needs. This includes tariff- and quota-free access for exports; enhanced debt relief for highly indebted poor countries; cancellation of official bilateral debt; and more generous official development assistance for countries committed to poverty reduction * Address the special needs of landlocked and small island developing states * Deal comprehensively with developing countries' debt problems through national and international measures to make debt sustainable in the long term * In cooperation with the developing countries, develop decent and productive work for the youth * In cooperation with pharmaceutical companies, provide access to affordable, essential drugs in the developing countries * In cooperation with the private sector, make available the benefits of new technologies—especially information and communications technologies	* Construction as a partner for development – study the role of construction in development in order to enhance it * Construction as a creator of wealth and less of a burden in imported inputs * Research on, and develop, construction industries in developing countries to enable them to play a role in globalizing economies * Effective logistics of construction in landlocked and small island developing states * Effective construction technology transfer in construction – from research to practice; from industrialized to developing countries * Partnership among industry, government, researchers * Global networks of researchers to study matters on construction and MDGs	* Same indicators as for MDGs 1 and 2

must be monitored and enforced through incentives and/or sanctions; and (8) social performance audits should be conducted with the same rigour as financial audits.

The ILO (2006: 3) suggests that municipalities should launch investment policies and programmes with the following elements: (1) employment-intensive infrastructure development for upgrading unplanned settlements and rehabilitating facilities for people affected by disasters and conflicts; (2) provision of social infrastructure for accessibility, water, health, education, markets, rehabilitation and preservation of national heritage; (3) organization and association building, negotiation and contracting capacity building for communities and informal economy operators, and support to SMEs; (4) provision of support to local governments, community groups and the private sector in pro-poor procurement and community contracting; (5) review of the local regulatory environment to improve their impact on job creation and the quality of jobs created; and (6) integrated employment and environmental impact assessments of urban investment plans.

Matthews *et al*. (2003, 2004) suggest that where appropriate, major construction firms should engage in national debates on policy reform to promote the value-adding role of construction firms in achieving government poverty reduction priorities. They should develop business strategies and tendering approaches which showcase their ability to contribute to the social performance of their clients. They should be proactive in developing relationships with communities in order to better target opportunities for community subcontracting and unskilled or semi-skilled employment at the poor. They should also develop a framework for reporting social performance, especially in areas of local content, skills training and social investment.

The WBCSD (2005) showcases several programmes and projects in which some of its member companies are taking action, moving beyond philanthropy and corporate social responsibility to business relationships. For example, under the ‘House-for-Life’ programme in Sri Lanka, launched in 2005, Holcim, the leading cement provider in the country, has formed a partnership with Ceylinco Grameen (a microfinance institution) to address the housing needs of the poorest citizens. Micro-entrepreneurs borrow money to buy a home designed as a shophouse, which provides each family the premises to run a business. Holcim provides the initial funds and technical skills, and Ceylinco administers the loan. In another example, a subsidiary of GrupoNueva (a company which deals in forest products, water systems and construction materials) in Guatemala (in collaboration with the government and two non-governmental organizations), has provided specially designed drip irrigation systems which help to reduce costs to farmers and ensures efficient availability of water throughout the year. This has helped the farmers to improve their production, and move their crop mix from subsistence to export-oriented produce.

THE FUTURE

Immensity of the task

Despite the continuing debate on their appropriateness, the MDGs are relevant goals which provide a framework for the development effort. The task is immense. It is estimated that by 2050, 85% of the world’s population of nine billion people will be living in developing countries (WBCSD 2005). The poorest countries are in a group of 35 Low-income Countries Under Stress also known as ‘fragile states’. The IEG (2006: 18) notes that they ‘are home to almost 500 million people, roughly half of whom live on less than a dollar a day. These countries face poor governance, conflict or post-conflict transitions, and a multiplicity of problems that make the achievement of development results particularly challenging.’ They face what the World Bank (IEG 2006) calls ‘the largest millennium development challenge-deficit’. They represent 9% of the developing world’s population, but 27% of the extreme poor.

Progress towards meeting the MDGs will not come only from additional foreign aid; supplementary solutions are required. For example, the IEG (2006) found that only two in five of the countries borrowing from the World Bank recorded continuous per capita income growth in 2000–05, and only one in five over 1995–2005. Thus, it is necessary to consider other contributors to the attainment of the MDGs, such as construction activity.

Research agenda

Researchers in construction management and economics (CM&E) can make an important contribution to the efforts to attain the MDGs. It is pertinent for each research study to seek to consider, among its objectives, the extent to which the findings would have an impact on the realization of relevant MDG targets.

CM&E researchers should help to relieve the severe constraints which the non-availability of relevant accurate information and data has on the improvement of both industry performance and research towards this end (Meikle and Grilli 1999). It is necessary to establish appropriate frameworks and methods for collecting, processing and disseminating comprehensive and accurate information on the construction industry, its processes and products in each country (Ofori (1988) presents a framework for such a data bank). Such information would facilitate the setting and monitoring of targets in each country, and inter-country comparisons. There could also be an international research project to determine industry, corporate and project level performance indicators, some of which have been highlighted in Table 1. These would facilitate the monitoring of the contribution of construction to the attainment of the MDGs.

There is need for greater understanding of the direct relationships between construction activity and some of the MDGs and other related key factors and phenomena. Some of the models which are required include: (1) relationship between construction activity and economic growth and development; (2) influence of various individual types of construction projects, such as a road, a bridge or a school, on economic growth; (3) the forward and backward linkages between construction and other sectors of the economy; (4) the amount of employment generated by a unit of different categories of construction work; (5) the relationship between improved construction industry performance and attainment of relevant MDG targets; and (6) the impact of foreign development assistance on economic growth and industry development.

Better understanding of the nature of the construction industry in developing countries is also required. In particular, more work is required on the informal sector, to explore its potential contribution to: (1) the enhancement of the capacity and performance of the industry as a whole; (2) determination of practical solutions which meet the housing needs of the poor; and (3) design and delivery of employment-intensive construction. The construction industry needs to know its stakeholders. More research on the real stakeholders of construction, and how to integrate their possible contributions to the projects is also required. Finally, other relevant topics to the development of the construction industries are: (1) effective public–private and foreign–local partnerships; and (2) effective technology transfer.

SUMMARY AND CONCLUSION: A DECLARATION

The construction industry has a critical role to play in the efforts being made to attain the MDGs. A declaration for the construction industry which could be considered for adoption by CM&E researchers, is now presented.

1. ‘We recognize that all construction is undertaken to benefit people. In this sense, the community is the most important stakeholder of the construction process and its needs and aspirations should be taken into consideration in all our work.
2. ‘We are aware that the buildings and infrastructure designed and produced by the construction industry are critical inputs into the development process which leads to the reduction of extreme poverty and enhancement of the quality of life of all people, and we should continuously seek ways and means to enhance the contribution of these inputs.
3. ‘We should provide value for money for society by producing cost effective, high quality, durable and easy to maintain buildings and items of infrastructure in the most time efficient and sustainable manner.
4. ‘We should select material inputs, technologies and procurement and project management approaches that enable construction activities to provide the maximum stimulus and spin-offs in the local economy, and employment opportunities for the community.
5. ‘We should establish employment practices and working conditions which promote the economic and social, well-being, and health of the industry’s workers, and are conducive to the safe and effective participation of women in construction.
6. ‘We urge researchers in CM&E to give priority in their work to how the construction industry can be enabled to realize the objectives outlined in clauses 1 to 6. In particular, they should develop indicators and benchmarks for assessing and monitoring the performance of the construction industry in each country with regard to the attainment of this objectives in this declaration.
7. ‘We should establish strong partnerships in each country among industry, government, the community and researchers to pursue the development of a construction industry with the attributes outlined in clauses 1 to 6.
8. ‘We call for the establishment of a global partnership among industry, governments and the communities to champion the development of the construction industries in developing countries to enable them to achieve the attributes outlined in clauses 1 to 6.’

REFERENCES

Abu-Ghaida, D and Klasen, S (2004) The costs of missing the Millennium Development Goal on gender equity. *World Development*, **32**(7), 1075–1107.

ADB (Asian Development Bank) (2006) *Annual report 2005*. Manila.

Baulch, B (2006) Aid distribution and the MDGs. *World Development*, **34**(6), 933–50.

Clemens, M A, Kenny, C J and Moss, T J (2007) The trouble with the MDGs: confronting expectations of aid and development success. *World Development*, **35**(5), 735–51.

Engineers Against Poverty (2006) *Modifying infrastructure procurement to enhance social development*. London: Engineers Against Poverty and Institution of Civil Engineers.

Fay, M, Leipziger, D, Wodon, Q and Yepes, T (2005) Achieving child-health-related Millennium Development Goals: the role of infrastructure. *World Development*, **33**(8), 1267–84.

Fay, M, Leipziger, D, Wodon, Q and Yepes, T (2007) Achieving child-health-related Millennium Development Goals: the role of infrastructure – a comment. *World Development*, **35**(5), 929–30.

Fedderke, J W, Perkins, P and Luiz, J M (2006) Infrastructural investment in long-run economic growth: South Africa 1875–2001. *World Development*, **34**(6), 1037–59.

Han, S S and Ofori, G (2001) Construction industry in China's regional economy. *Construction Management and Economics*, **19**, 189–205.

Hillebrandt, P M (2000) *Economic theory and the construction industry*. 3ed. Basingstoke: Macmillan.

Hillebrandt, P M (2006) The construction industry and its resources: a research agenda. *Journal of Construction in Developing Countries*, **11**(1), 37–52.

Howe, J and Bantje, H (1995) *Technology choice in civil engineering practice: experience in the road sector.* Geneva: International Labour Office.

IEG (Independent Evaluation Group of the World Bank) (2006) *Annual review of development effectiveness 2006: getting results*. Washington, DC: World Bank.

ILO (2003) Labour-based technology: a review of current practice. *In*: *Proceedings of the Seminar on Labour-based Technology for Poverty Reduction*, 13–17 October 2003, Arusha, Ministry of Works, Tanzania and ASIST Africa.

ILO (2006) *A strategy for urban employment and decent work*. Geneva: ILO.

Matthews, P, Neal, I, Warner, M and Tanner, A (2003) *Learning from Lot 3 of the Java–Bali 500kv transmission line construction project, Indonesia*. London: Engineers Against Poverty, Overseas Development Institute and Balfour Beatty Group.

Matthews, P, Neal, I, Stuttle, J, Herd, C and Warner, M (2004) *Learning from AMEC's oil and gas asset support operations in the Asia-Pacific region.* Engineers Against Poverty and Overseas Development Institute.

Maxwell, S (2003) Heaven or hubris: reflections on the 'new poverty agenda'. *Development Policy Review*, **21**(1), 5–25.

Meikle, J and Grilli, M T (1999) Measuring European construction output: problems and possible solutions. *In*: *Proceedings, Second International Conference on Construction Industry Development and First Conference of TG29 on Construction in Developing Countries*.

Meintjes, I, Bowen, P and Root, D (2007) HIV/AIDS in the South African construction industry: understanding the HIV/AIDS discourse for a sector-specific response. *Construction Management and Economics*, **25**, 255–66.

Howe, J and Bantje, H (1995) *Technology choice in civil engineering practice: experience in the road sector.* Geneva: International Labour Office.

IEG (Independent Evaluation Group of the World Bank) (2006) *Annual review of development effectiveness 2006: getting results*. Washington, DC: World Bank.

ILO (2003) Labour-based technology: a review of current practice. *In*: *Proceedings of the Seminar on Labour-based Technology for Poverty Reduction*, 13–17 October 2003, Arusha, Ministry of Works, Tanzania and ASIST Africa.

ILO (2006) *A strategy for urban employment and decent work*. Geneva: ILO.

Matthews, P, Neal, I, Warner, M and Tanner, A (2003) *Learning from Lot 3 of the Java–Bali 500kv transmission line construction project, Indonesia*. London: Engineers Against Poverty, Overseas Development Institute and Balfour Beatty Group.

Matthews, P, Neal, I, Stuttle, J, Herd, C and Warner, M (2004) *Learning from AMEC's oil and gas asset support operations in the Asia-Pacific region.* Engineers Against Poverty and Overseas Development Institute.

Maxwell, S (2003) Heaven or hubris: reflections on the 'new poverty agenda'. *Development Policy Review*, **21**(1), 5–25.

Meikle, J and Grilli, M T (1999) Measuring European construction output: problems and possible solutions. *In*: *Proceedings, Second International Conference on Construction Industry Development and First Conference of TG29 on Construction in Developing Countries*.

Meintjes, I, Bowen, P and Root, D (2007) HIV/AIDS in the South African construction industry: understanding the HIV/AIDS discourse for a sector-specific response. *Construction Management and Economics*, **25**, 255–66.

Millennium Project (2005) *Investing in development: a practical plan to achieve the Millennium Development Goals*. New York: United Nations Development Programme.

Ofori, G (1988) A central data bank for construction. *Habitat International*, **12**(1), 87–94.

Ofori, G (2000) Challenges for construction industries in developing countries. *In*: *Proceedings, Second International Conference of the CIB Task Group 29*, November, Gaborone, Botswana, 1–11.

Ravallion, M (2007) Achieving child-health-related Millennium Development Goals: the role of infrastructure – a comment. *World Development*, **35**(5), 920–8.

Sahn, D E and Stifel, D C (2002) Progress toward the Millennium Development Goals in Africa. *World Development*, **31**(1), 23–52.

The Hindu (2005) Power major problem in infrastructure deficit India: PC. *The Hindu*, 16 November.

UN (2000) Resolution adopted by the General Assembly 55/2 – United Nations Millennium Declaration. New York.

Vijayan, K C and Neo, M (2007) Errant contractors hit with stop-work orders. *The Straits Times*, 25 May, p. H2.

WBCSD (2005) *Business for development: business solutions in support of the Millennium Development Goals*. Geneva.

Wells, J (1986) *The construction industry in developing countries: alternative strategies for development*. London: Croom Helm.

FIRST AND SECOND PRICE INDEPENDENT VALUES SEALED BID PROCUREMENT AUCTIONS: SOME SCALAR EQUILIBRIUM RESULTS

Martin Skitmore[1]

School of Urban Development, Queensland University of Technology, Gardens Point, Brisbane Q4001, Australia

A great body of knowledge exists on the theory of auctions and competitive bidding that is of potential relevance to construction contract tendering. Most of this, however, contains assumptions – such as perfect information – that are unlikely to be tenable in practice. The aim, therefore, is to examine the effects of relaxing some of the more restrictive of these assumptions in the construction tendering context. In particular, the effects of additive and multiplicative (scalar) mark-ups in equilibrium are examined for first and second price auctions in situations where bidders have different, uncertain, costs. This is illustrated first by Monte Carlo simulation – by which bids generated randomly from a normal distribution for six bidders and mark-ups are applied systematically for each bidder in turn until equilibrium is reached. An extensive numerical analysis is then applied to obtain equilibrium results for both mark-up values and expected profit from the simple symmetric case through to more complex asymmetric cases for the uniform and normal distributions. In general, it is found that first price auction bidders with relatively high c_v levels and a larger number of bidders involved bid higher in equilibrium but can expect little profit unless the number of bidders involved is small. Where there are asymmetries, stronger bidders (i.e. those with lower costs and less variability) bid much higher and achieve much higher profits in equilibrium. From the seller's point of view, it is cheaper, in equilibrium, to have a homogeneous group of low variability bidders. The work contributes to the body of knowledge on the economic theory of auctions by closing some of the gap between theory and practice.

Keywords: auction theory, bidding, equilibrium, procurement tendering.

INTRODUCTION

While the practice of auctioning goes back to ancient times,[1] the earliest academic treatments are relatively recent, with the contributions of Friedman (1956) from an operations research (decision theoretic) perspective, Vickery (1961) from a game theoretic perspective and Gates (1967) from what has been termed the tendering theory perspective (Runeson and Skitmore 1999). In general, decision and tendering theory seek to inform bidders while game theory seeks to inform sellers. All three approaches have some impractical assumptions. Decision theory (DT), for example, is essentially static, in that it assumes any given bidder's opponents to bid with either a random or constant mark-up. Game theory (GT) on the other hand assumes all bidders somehow always bid optimally irrespective of the value of their cost estimates.

[1] rm.skitmore@qut.edu.au

Of the three, progress has been dominated by the development of the game theoretic approach into a full-blown Bayesian–Nash equilibrium theory, now termed auction theory (AT), under the standard economic assumption of rational utility maximization – so that now 'the auction problem can be understood by applying the usual logic of marginal revenue versus marginal cost' (Klemperer, 1999: 312).[2] One of the major outcomes of this theoretical development has been to discover the equilibrium bidding strategies for independent *private value* (IPV) auctions. This assumes an idealized form of valuation process by which, in procurement auction terms, each bidder estimates the costs involved perfectly accurately. For example, Vickrey (1961) showed that if bidders are symmetric, that is, the resulting bids are assumed to be drawn from the same probability distribution, the expected payment for the client/building owner in English first price (open-cry), sealed bid, second price sealed bid (Vickrey) and Dutch (descending) auctions is the same in equilibrium.

As an alternative to IPV auctions, in which it is assumed that bidders have perfectly estimated but different true costs, the *common value* (CV) model has been studied, in which all bidders are assumed to have the same, but imperfectly estimated, true costs (e.g. Wilson 1969). Clearly, the private and common value assumptions are special cases of a more general model which contains *both* imperfect information *and* different costs for each bidder. One version of this that has received considerable attention (e.g. Myerson 1981; Riley and Samuelson 1981; Milgrom and Weber 1982) is based on the idea of signals. Here it is assumed that each bidder receives a private value signal (cost estimate), but allows each bidder's value (cost) to be a function of all the signals (other bidders' cost estimates). With a suitable definition of this function in terms of the assumed conditional probabilities involved, Milgrom and Weber (1982) were able to develop the general model needed, termed the *affiliated values* model, by using a natural generalization of the monotone likelihood ratio property commonly used in statistical models. This provides several equilibrium results, the most important of which is that the English auction generates the lowest bids followed by the second price and, finally, the Dutch and first price auction.

Milgrom and Weber's work, however, is concerned with the general properties of symmetric auction models when types (values/signals) are *not* independently distributed (Monteiro and Moreira 2006: 1), making the affiliation assumption, as Milgrom and Weber point out, necessarily restrictive. Although, as they say, it may accord well with the qualitative features of some situations, such as the sale of works of art, there are many other situations where it does not (Monteiro and Moreira 2006: 1; de Castro 2004). In fact, de Castro (2004) is particularly critical, claiming the affiliated values assumption to be 'very restrictive'; much more cumbersome to manipulate theoretically, with the monoticity of equilibrium hard to maintain; and leading to conclusions that are misleading if applied to reality. In his view, a return to the search for non-monotonic equilibria is urgently needed, citing Araujo *et al.*'s (2003) general existence result of non-monotonic symmetric equilibria with independent types. Araujo *et al.* (2004), among others, have continued this work to examine multidimensional situations. Meanwhile Lebrun (1996, 1999) has obtained some results for asymmetric first price auctions, that is when bidders' values are differently distributed, while Cantillon (2004) has considered both first and second price asymmetries. Guth *et al.* (2004) provide a summary of much of the asymmetry work. No treatment appears yet to have been made of the equilibria for the asymmetric general independent values (GIV) model which contains both imperfect information *and* different costs – most likely because of the difficulties involved in finding analytical solutions (Rothkopf *et al.* 2003: 72).

To examine the theory further for construction contract auctions, a starting point is to return to the original theme and consider the GIV model where bidders have, independently, both different costs and imperfect estimates of them. In addition, unlike AT where unbounded rationality is assumed, the goal is to maximize profits by the more practical means of mark-up manipulation. This involves finding equilibrium in DT-like scalar strategies rather than AT functions (Rothkopf *et al.* 2003: 73).

Equilibrium multiplicative mark-up strategies in a *symmetric* common value (imperfect estimates but same costs) sealed bid game theoretic setting have been reported in several studies. Rothkopf (1969, 1980a), for example, solves the *n* bidder Weibull distributed first price (FPA) situation analytically, while Oren and Rothkopf (1975) extend this to the situation where a bidder's strategy in one auction affects his competitors' behaviour in subsequent auctions, modelling bidding in a sequence of auctions as a multistage control process. Smith and Case (1975), on the other hand, consider the two bidder loglogistic common value FPA situation for both pure and mixed (randomized) strategies, while Rothkopf (1991) also considers the *n* bidder common value Weibull FPA and second price (SPA) situations in which bidders may submit two or more bids and then withdraw some bids after bids are opened.

For the *asymmetric* situation, Rothkopf (1969, 1980a) has solved the equilibrium multiplicative mark-up strategies for the two bidder *common variance* Weibull distributed FPA situation analytically, and the *n* bidder case numerically.[3] No results have been reported for the fully asymmetric imperfect estimates case, where both location and scale parameters are unique to each bidder. Neither have any equilibrium results been reported for scalar strategies other than multiplicative for either the symmetric or asymmetric situation, with the exception of Rothkopf (1980b), who found, analytically, the equilibrium linear (affine) FPA mark-ups in the Weibull common value *n* bidder situation.

In general, therefore, it is concluded that, despite the difficulties involved in equilibrium asymmetric modelling with cost uncertainties, multiplicative mark-up models at least have had some success. In this paper, both the equilibrium multiplicative *and* additive mark-ups are considered within a general linear mark-up strategy. First, an example is provided describing how results may be obtained by straightforward Monte Carlo simulation to illustrate the simple concept underlying the analysis and identify some of the practical problems involved. Next, a numerical analysis is undertaken for the FPA and SPA for the uniform and normal composite densities and the results provided for some of the more obvious regularities detected. Finally, some practical observations are volunteered on the relevance of the analysis to construction contract bidding in practice.

SIMULATION METHOD

Analysis

Figure 1 (all Figures are in the Appendix) shows the FPA results of simulating 100 000 values for each 0.1% change in (multiplicative) mark-up values by a bidder, assuming other bidders are all bidding with the same mark-up as each other. In this illustration, a typical construction contract auction situation is assumed in which there are six bidders in total, each drawing cost estimates from a normal distribution with 4.3% coefficient of variation. Overheads are calculated by the CIC formula converted to rebased HK$, with project size (HK$value) being loglognormal (mean = 2.872829, s.d. = 0.061078).

To understand Figure 1, first assume all opposing bidders apply a 12% mark-up. The expected profit is then recorded for the reference bidder over series of reference bidder mark-up values. The results of this are shown in Figure 1 as the curve marked ‘12%’. The optimal mark-up, i.e., the mark-up value that provides the maximum expected profit, occurs at the upper turning point of this curve at 6.7% mark-up (point A), giving an expected profit of $21.4m.

Now assume all opposing bidders apply a 11% mark-up. Again the reference bidder’s expected profit is recorded over a series of reference bidder mark-up values and plotted, this time at the curve marked 11%. In this case the optimal mark-up is 6.5%, giving an expected profit of $15.5m. Figure 1 shows the results of this repeated for 10%, … , 5%. Line A–B connects the optimal mark-up values.

For the game theoretic solution the usual approach is to use the Nash criterion. That is, the solution occurs where any alternative solution for any player produces a worst result overall. This can be reached by trial and error as follows. In this case, from Figure 1, assume that all bidders bid at 12% mark-up. Now, as mentioned above, the reference bidder can maximize his profits by bidding a 6.7% mark-up. Unlike the DT approach, where competitors are assumed to be unable to change, the game theoretic approach assumes that all bidders know that bidding at 6.7% mark-up is best against competitors bidding at 12% mark-up. In other words, it has to be allowed that all bidders will bid at 6.7% mark-up under the assumption that their competitors are bidding at 12% mark-up.

Now, assume that all bidders are bidding at 6.7% mark-up. This will be on the line C–D. Our bidder’s best mark-up now is the point on A–B at the same value of the y-axis, i.e. around 8.25% mark-up. Following the same reasoning then, if all bidders bid at 8.25% mark-up, our bidder should bid at around 7% mark-up. Repeating this process enough times results in convergence at 7.4% mark-up, where no bid higher or lower by any bidder will produce a better result. This, then, is the equilibrium solution and occurs where the two lines A–B and C–D intersect, in this case producing an expected profit of approximately $2m.

Figures 2 and 3 show the solution of the SPA. Again A–B gives the optimal results, showing 0% mark-up to be optimal when competitors all bid at greater than 5% mark-up, but increasing quite rapidly when they bid less. The Nash outcome (Figure 3) is 3.6%, producing an expected profit of $1.6m.

Comment

A few issues arise out of this illustrative analysis by simulation. One is that the expected profit for some optimal mark-up values is sometimes negative. That is, it can be an expected loss. Of course, this is unlikely to be the case in a live situation as presumably bidders will prefer not to bid at all rather than make a loss under equilibrium.[4]

Another issue is that using Monte Carlo simulation, although very fast on a modern PC, is still quite time consuming (Figure 1 takes around one hour to produce). While it is useful enough for a one-off auction situation with a fixed set of parameters, it is unlikely to be practicable in an extensive analysis aimed at identifying general relationships and regularities. To do this necessarily requires a massive reduction in computing time. In previous similar studies, the most popular approach to this is to derive general results by analytical means. However, as has been already observed, this is seldom possible beyond the relatively simple symmetric IPV and CV assumptions.

An intermediate approach that has been used previously with some success for more complex situations is numerical analysis. This involves deriving formulae that can be solved by a means other than by finding the solution of a set of differential equations. In this case, the formulae for calculating the expected profit is used together with numerical maximization software from the Numerical Algorithms Group (NAG) Library. The formulae developed are presented in the Appendix for the general linear (additive and multiplicative) mark-up case.

NUMERICAL METHOD: SOME FPA RESULTS

The Nash solution is easily found numerically by using Equation A.2 to first find the mark-up values, $\tilde{v}_{1i}$ and $\tilde{v}_{2i}$ that maximize expected profit $\tilde{E}_i = E_{(k)i}[\theta]$ for bidder *i*, then finding $\tilde{v}_{1j}$ and $\tilde{v}_{2j}$ that maximize $\tilde{E}_j = E_{(k)j}[\theta]$ for the next bidder $(j = 1, \ldots, n;\ j \neq i)$ assuming the first bidder is using $\tilde{v}_{1j}$ and $\tilde{v}_{2j}$, etc., after assuming appropriate starting values. Upon convergence, $v_{1i}^* = \tilde{v}_{1i}$ and $v_{2i}^* = \tilde{v}_{2i}$, etc., $(i = 1, \ldots, n)$ are the equilibrium mark-up values, with associated equilibrium expected profits, $E_i^* = \tilde{E}_i$, etc.

Additive equilibrium mark-up (v_1^*)

In reality, it is most likely that the true parameters for all bidders will be different, i.e. $\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n$ and $\sigma_1 \neq \sigma_2 \neq \ldots \neq \sigma_n$ (Skitmore 1991). However, it is of interest to see what the effects are of some simplifying assumptions. The simplest of these is where the value of all bidders' parameters are equal to our own, i.e. $\mu_1 = \mu_2 = \ldots = \mu_n$ and $\sigma_1 = \sigma_2 = \ldots = \sigma_n$. This is equivalent to the symmetric *common value* model, many of the properties of which have already been established for the formless bid function. However, these are now considered here for the first time for the additive equilibrium mark-up, v_1^*, by fixing $v_2 = 1$. Then the effects are considered of $\mu_1 = \mu_2 = \ldots = \mu_n$ while retaining $\sigma_1 \neq \sigma_2 \neq \ldots \neq \sigma_n$. This is followed by the alternative $\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n$ with $\sigma_1 = \sigma_2 = \ldots = \sigma_n$. Finally, the most general case is examined of $\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n$ and $\sigma_1 \neq \sigma_2 \neq \ldots \neq \sigma_n$.

Common parameters (the symmetrical common value model)

Figure 4 gives the results for v_1^* and E^* for the two bidder symmetric common value model for the uniform distribution for a range of σ values. This indicates that $v_1^* = \sigma\sqrt{3}$ (or $v_i^* = \frac{b-a}{2}$ where *b* and *a* are the upper and lower supports). This is the dominant strategy and true for any value of *n* and μ. Also, $E^* = \frac{2\sigma\sqrt{3}}{n(n+1)}$ (or $E^* = \frac{b-a}{n(n+1)}$), which is true for any value of μ. The equilibrium expected revenue (client's payment) is $R^* = \mu + nE^*$ (or $R^* = \frac{a(n-1)+b(2b+n)}{2(n+1)}$).

v_1^* and E^* are also independent of μ (but not *n*) for the normal distribution provided σ is proportional to μ. This enables the results, although additive, to be stated in more conventional terms as a percentage over a range of coefficients of variation (c_v). These are shown in Figure 5 and Figure 7 for v_1^* and E^* respectively for both the normal (blue) and uniform (red) distributions and are true for any value of μ. As these Figures show, the relationships between c_v and v_1^* (and c_v and E^*) are linear with both $v_1^* \to 0$ and $E^* \to 0$ as $c_v \to 0$. Figure 6 gives an alternative representation of the v_1^* results for the normal distribution, showing an abnormality of values for smaller values of *n* as c_v increases.

Common μ (the asymmetric common value model)
For the asymmetric common value model, $\mu_1 = \mu_2 = \ldots = \mu_n$ and $\sigma_1 \neq \sigma_2 \neq \ldots \neq \sigma_n$. Let $\sigma_{(1)}$ denote the smallest value of σ_i $(i = 1,2,\ldots,n)$ then, for the uniform distribution, $v_{1i}^* = \sigma_i\sqrt{3}$ for $\sigma_i > \sigma_{(1)}$ as with the symmetric model, while $v_{1i}^* > \sigma_i\sqrt{3}$ for $\sigma_i = \sigma_{(1)}$. This is again the dominant strategy and true for any value of *n* and μ. Also, $E_i^* < \dfrac{2\sigma_i\sqrt{3}}{n(n+1)}$ for $\sigma_i > \sigma_{(1)}$ and $E_i^* > \dfrac{2\sigma_i\sqrt{3}}{n(n+1)}$ for $\sigma_i = \sigma_{(1)}$ – again true for any value of μ ($R^* = \mu + \sum_i^n E_i^*$ for all asymmetric cases).

For the normal distribution, the only discernible trend is for the two bidder case, where v_1^* and E^* are proportional to $\dfrac{\sigma_i}{\sigma_j}$. That is $v^*_{1\frac{\sigma_i}{\sigma_j}} = \sigma_i v^*_{1\frac{1}{\sigma_j}}$ and $E^*_{\frac{\sigma_i}{\sigma_j}} = \sigma_i E^*_{\frac{1}{\sigma_j}}$ Figure 8 shows the results for $1/\sigma_j$ (v_1^* and E^* are the same for both bidders) for both uniform and normal distributions. These are true for any value of μ.

Common σ
Similarly, where $\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n$ and $\sigma_1 = \sigma_2 = \ldots = \sigma_n$, $v_{1i}^* = \sigma_i\sqrt{3}$ for the uniform distribution except for the bidder with the lowest μ value, in which case $v_1^* > \sigma_i\sqrt{3}$ for that bidder. $E_i^* < \dfrac{2\sigma_i\sqrt{3}}{n(n+1)}$ except for the bidder with the lowest μ value, in which case $E_i^* > \dfrac{2\sigma_i\sqrt{3}}{n(n+1)}$ for that bidder.

For the normal distribution, the only discernible trend again is for the two bidder case. Figures 9 and 10 show the values of v_{1i}^* and E_i^* for a range of $\mu_i - \mu_j$ for values of σ common to each bidder for both uniform and normal distributions.

Heterogeneous case
For the complex case of $\mu_1 \neq \mu_2 \neq \ldots \neq \mu_n$ and $\sigma_1 \neq \sigma_2 \neq \ldots \neq \sigma_n$, no general results are obtainable except for the two bidder common c_v case. Figures 11 and 12 give the results for v_{1i}^* and E_i^* respectively for c_v = 0.01, 0.05 and 0.10 for a range of $\dfrac{\sigma_i}{\sigma_j}$ values for both uniform and normal distributions for $\mu_i = 1$ (the results being a multiple of μ_i, i.e., $v_{1i\mu_i}^* = \mu_i v_{1i}^*$ and $E_{i\mu_i}^* = \mu_i E_i^*$).

Multiplicative equilibrium mark-up (v_2^*)

Common parameters (the symmetrical common value model)

For the symmetric common value model, v_2^* and E^* are proportional to the coefficient of variation, c_v. Figure 13 gives the results for the two bidder situation for the uniform and normal distributions. This shows $v_2^* \to 1$ as $c_v \to 0$ and $v_2^* \to 0$ as $c_v \to \infty$. In addition, for the uniform distribution, $v_2^* = \frac{1}{2} + \frac{\sqrt{3}}{6}$ at $c_v = 1$ and $v_2^* = 1 + \frac{\sqrt{3}}{3}$ at $c_v = \frac{1}{2}$, reaching a maximum of exactly 1.6 where c_v is exactly 0.625. For the normal distribution, the $v_2^* = 1.3745$ at $c_v = 1$ and $v_2^* = 2.0459$ at $c_v = \frac{1}{2}$, reaching a maximum of 2.1 where c_v is 0.59.

The associated expected profit is a multiple of σ, i.e. $E_\sigma^* = \sigma E^*$ for both uniform and normal distributions. Figure 13 shows the values of E^* for $\sigma = 1$. This indicates that $E^* \to \frac{\sigma}{\sqrt{3}}$ as $c_v \to 0$ and $E^* \to 0$ as $c_v \to \infty$. In addition, for the uniform distribution, $E^* = -\frac{\sigma}{3}$ at $c_v = 1$, reaching a minimum of exactly $-\frac{\sigma\sqrt{3}}{5}$ where c_v is exactly $\frac{\sqrt{3}}{2}$. For the normal distribution, E^* reaches a maximum of 0.6437 where c_v is 0.202 and a minimum of –0.3057 at c_v = 1.408.

Figure 14 shows the results for the *n* bidder situation up to $c_v \leq 0.3$ (convergence becomes highly dependent on starting values for *n*>2 at c_v > 0.3). This indicates that $v_2^* \to 1$ for any *n* bidders as $c_v \to 0$. The associated expected profit for the *n* bidder situation is again a multiple of σ and is shown in Figure 15 for $\sigma = 1$.

Asymmetric model (common c_v)

For the case of two bidders with a common c_v, the v_2^* is proportional to their standard deviations. Figure 16 shows the v_2^* for bidder *i* over a range of $\frac{\sigma_i}{\sigma_j}$ values where both bidders have typical values of c_v = 0.01, 0.05 and 0.10. This suggests that $v_2^* \to \infty$ as $\frac{\sigma_i}{\sigma_j} \to 0$ and $v_2^* \to 1 + 2c_v$ as $\frac{\sigma_i}{\sigma_j} \to \infty$ (the results for $\frac{\sigma_i}{\sigma_j} = 1$ are given in the previous section). Although convergence does occur for typical values, no easily discernible patterns of results were found for expected profit.

NUMERICAL METHOD: SOME SPA RESULTS

Additive equilibrium mark-up (v_1^*)

For the uniform distribution, no second price v_1^* can be found except for the symmetric common value model with *n* = 2, where the v_1^* is zero (if and only if the starting point is zero), with expected profit of $E^* = \frac{\sigma_i\sqrt{3}}{n(n+1)} = \frac{\sigma_i\sqrt{3}}{6}$ (exactly half the value of the FPA[5]) and expected revenue (client's payment) again of $R^* = \mu + nE^* = \mu + 2E^*$.

Second price solutions for the normal distribution are only obtainable for the common value model and when the starting point is zero. As with the first price arrangement, the v_1^* and associated expected profit values are a multiple of σ. Table 1 shows these for $\sigma = 1$. With the exception of R^*, which is again $\mu + nE^*$, all results are independent of the value of μ. It is interesting to note that expected profit at the SPA v_1^* is close to half the expected profit at the FPA v_1^* – equivalent to the known affiliation result that the SPA generates a better return to the seller than does the first price equivalent (Milgrom and Weber, 1982: 1095).

Table 1: Equilibrium results for the standard normal distribution $(E[C] = \mu = 0)$

	1st price				2nd price			
n	v_1^*	$P_{(1)}(v_1^*, v_2 = 1)$	E^*	R^*	v_1^*	$P_{(1)}(v_1^*, v_2 = 1)$	E^*	R^*
2	1.7725	0.5000	0.6041	1.2083	0.0000	0.5000	0.2821	0.5642
3	1.5074	0.3333	0.2204	0.6611	0.3257	0.3333	0.1086	0.3257
4	1.5071	0.2500	0.1194	0.4777	0.5356	0.2500	0.0596	0.2386
5	1.5478	0.2000	0.0770	0.3848	0.6879	0.2000	0.0386	0.1929
6	1.5954	0.1667	0.0547	0.3282	0.8063	0.1667	0.0274	0.1645
7	1.6420	0.1429	0.0414	0.2898	0.9025	0.1429	0.0207	0.1451
8	1.6855	0.1250	0.0327	0.2619	0.9831	0.1250	0.0164	0.1309
9	1.7257	0.1111	0.0267	0.2406	1.0523	0.1111	0.0133	0.1200
10	1.7625	0.1000	0.0224	0.2238	1.1127	0.1000	0.0113	0.1113
15	1.9093	0.0667	0.0116	0.1734				
30	2.1631	0.0333	0.0040	0.1235				

Multiplicative equilibrium mark-up (v_2^*)
Doesn't converge!

DISCUSSION

Being the first time such an analysis has been undertaken, perhaps the first and most important result of work detailed here is that there are any results at all! Unlike the 'higher' analysis (Rothkopf and Harstad 1994) for conventional analytical approach in AT, being reduced to obtaining numerical solutions is an uncertain business. First there is the problem of finding suitable starting values. Using standard minimizing software routines, as has been done here, can make this a sensitive issue as was often the case for the $n > 2$, and for all the SPA analyses attempted. Next there is the problem of suboptimal solutions and failure to converge. In several cases the iteration loops around a 'strange attractor', fluctuating between two or three values for each bidder. Perhaps most important of all is the possibility of errors in the computer program. There is a profound lack of earlier analyses results upon which to carry out replication tests. In the end, it was possible to adapt the program to replicate some of Maskin and Riley's (2000) and Li and Riley's (1999) asymmetric IPV results although only in a limited way as they use bid functions rather than the scalar strategies used here. As a further precaution, the integration routines were all subject to intensive testing by Monte Carlo simulation.

Turning to the results themselves (Table 2 in the Appendix provides a summary), it is clear that a good number of 'solutions' are obtainable for the FPA symmetric and $n = 2$ situations, with the uniform distribution in particular providing some elegant-looking relations that can surely be derived analytically. This is not surprising as the usual analytical approach is to start with the two bidder symmetric uniform situation before moving on to the *n* bidder situation, followed by a distribution free treatment (the asymmetric situation is often intractable).

Of course, for generality, the results have been obtained for as wide a range of parameters as possible. Construction contract bidding, however, is concerned with a more restricted range. The coefficient of variation, for example, is generally taken to be around 0.05 to 0.10 for construction bidding (Skitmore 1989: Table 7.2). Within this narrower range, the symmetric FPA results suggest the c_v to be rather more important than the number of bidders, with v_1^* ranging between 7–11% for 2–30 bidders at $c_v = 0.05$ to 15–22% for 2–30 bidders at $c_v = 0.10$ (Figures 5 and 6) for these, with a similar order of magnitude for v_2^* (Figure 14). The opposite effect occurs with the associated expected profit, however, where E^* is always small for a large number of bidders, irrespective of c_v. For a small number of bidders, E^* becomes significantly higher generally irrespective of c_v for the multiplicative mark-up (Figure 15) but only for larger c_v values for the additive mark-up (Figure 7) In terms of the differences between the uniform and normal assumption, the v_1^* for the uniform with any number of bidders is approximately the same as that for around eight normal bidders, and quite similar to the normal E^* (Figure 7). The v_2^* for the uniform on the other hand, is generally quite similar when a higher number of bidders is involved, which is the reverse of the situation for the normal distribution (Figure 14).

It is not possible to judge the effect of the number of bidders in the asymmetric situation as no trends were observed for $n > 2$. For the two bidder situation though, the advantage of one (stronger) bidder having a smaller mean or variance is very much pronounced in the v_1^* and E^* values (Figures 9–12), with the results for the uniform and normal being very similar for common variance (Figures 9–12) but with the uniform v_1^* and E^* always being higher than the normal equivalent for the common mean (Figure 8). Similarly, the v_2^* results for the stronger (lower variance) bidder are also very striking (Figure 16), with the c_v level being much more important for the higher variance bidder.

CONCLUSIONS

This paper has presented some numerical equilibrium additive and multiplicative mark-up results for the uniform and normal first and second price construction contract auctions, in which bidders are assumed to have both different costs and imperfect estimates of them. Overall, and bearing in mind the limitations mentioned below, it is clear from this analysis that FPA bidders with relatively high c_v levels and a larger number of bidders involved bid higher in equilibrium but can expect little profit unless the number of bidders involved is small. Where there are asymmetries, stronger bidders (i.e. those with lower costs and less variability) bid much higher and achieve much higher profits in equilibrium. From the seller's point of view, the implications are equally clear. It is cheaper, in equilibrium, to have a homogeneous group of low variability bidders – a result anticipated by Flanagan and Norman

(1985), which they interpret as implying the need for good quality of information to bidders experienced in the type and size of contract under auction (p.159).

There are also indications that the use of SPA and greater numbers of bidders may also be beneficial to sellers, but the analysis is quite limited in this respect – particular as the cost of bidding has not been included. Other well-known limitations of equilibrium analysis are worthy of mention. A major issue is that bidders might not behave optimally (Flanagan and Norman 1984: 155–6), which raises the question of what do about this (Thaler 1988) to at least take advantage of the opportunity costs at stake. As must be expected, the economic basis of equilibrium results assumes all bidders to be acting rationally and so such an analysis is certainly going to lie outside the boundary of economics. A further important issue concerns the limitations of auction theory as a branch of game theory, in that the competitor behaviour is assumed to be limited only to Nash type responses to the optimal moves of others. As Rothkopf and Harstad (1994) comment, many of the common assumptions of game theoretic models – symmetry, common knowledge, isolation, fixed number of bidders and unbending rules – are suspect from an applications point of view. Similarly, there is no allowance here for changes in market conditions (supply of, and demand for, contractors' services) or the capacity of the contractors (Runeson and Skitmore 1999). Finally, as has been mentioned in several seminal contributions in the construction literature (e.g. Raftery 1991; Hillebrandt 2000; Runeson 2000), the extent of the uncertainties involved in forecasting future costs as well as the behaviour of competitors and the market in general requires contract bidders to devote a far greater amount of energy and resources to marketing than is currently admitted in the economic theory of auctions.

ACKNOWLEDGEMENTS

This work has been continuing for many years, during which time I have been fortunate enough to have been ably assisted by a variety of people, the most prominent of which include mathematician/statisticians Roy Thomas, Ernest Wilde, Mike Patefield and John Pemberton all of Salford University. More recently, I am indebted to Ross McVinish of QUT and Flavio Menezes of the University of Queensland. The former, for his help in articulating the GIV model and its limitations. The latter, for summarizing the main AT results and *cul de sacs* to date and the likely prospects for asymmetric models and mark-up form bid functions in general. Thanks also go to Michael Rothkopf for his comments on an earlier draft, drawing my attention to his work on equilibrium linear mark-ups and kind encouragement in general.

NOTES

1. Cassady (1967) mentions a report by the Greek historian Herodotus, who described the sale by auction of women to be wives in Babylonia around the fifth century BC.
2. The most notable contributions have come from Griesmer *et al.* (1967), Wilson (1969, 1977), Milgrom (1979, 1981), Riley and Samuelson (1981), Myerson (1981) and Milgrom and Weber (1982) – see Klemperer (1999) for a comprehensive account.
3. See Rothkopf *et al.* (2003) for references to other examples of multiplicative mark-ups in the game theory approach.
4. I am indebted to Michael Rothkopf for pointing this out.
5. Note that, while AT predicts the FPA and SPA to be the same for this symmetrical case, this analysis, unlike AT, is restricted to the profit maximization by mark-up manipulation, which may account for the difference in outcome.

REFERENCES

Araujo, A, Castro, L I and Moreira, H (2003) Non-monotonic auctions. Working Paper, Instituto Nacional de Mathematica Pura Aplicada (IMPA).

Araujo, A, Castro, L I and Moreira, H (2004) Pure strategy equilibria or multidimensional and non-monotonic auctions. Working Paper, IMPA.

Cantillon, E (2004) *The effect of bidders' asymmetries on expected revenue in auctions*, available at www.people.hbs.edu/ecantillon/benchmark.pdf (accessed 21 May 2006).

Cassady, R Jr (1967) *Auctions and auctioneering*. Berkeley and Los Angeles: University of California Press.

Chu (2007) BBC news website http://news.bbc.co.uk/2/hi/technology/6412057.stm.

De Castro, L I (2004) Is affiliation a good assumption? Working Paper, IMPA.

Flanagan, R and Norman, G (1985) Sealed bid auctions: an application to the building industry. *Construction Management and Economics*, **3**, 145–61.

Friedman, L (1956) A competitive bidding strategy. *Operations Research*, **1**(4), 104–12.

Gates, M (1967) Bidding strategies and probabilities. *ASCE Journal of the Construction Division*, **93**(CO1), Mar, 75–107.

Griesmer, J H, Levitan, R E and Shubik, M (1967) Toward a study of bidding processes part IV: games with unknown costs. *Naval Research Logistics Quarterly*, **14**, 415–33.

Guth, W, Ivanova-Stenzel, R and Wolfstetter, E (2004) *Bidding behaviour in asymmetric auctions: an experimental study*, available at www.wiwi.hu-berlin.de/wt1/papers/2004/Asym_auctions.pdf (accessed 21 May 2006).

Hillebrandt, P M (2000) *Economic theory and the construction industry*. 3ed. London: Macmillan Press Ltd.

Hong, H and Shum, M (2003) Economic models of asymmetric ascending auctions. *Journal of Econometrics*, **112**, 327–58.

Klemperer, P (1999) Auction theory: a guide to the literature. *Journal of Economic Surveys*, **13**(3), 227–86.

Lebrun, B (1996) Existence of an equilibrium in first price auctions. *Economic Theory*, **7**(3), 421–43.

Lebrun, B (1999) First price auctions in the asymmetric N bidder case. *International Economic Review*, **40**(1), 125–42.

Li, H and Riley, J G (1999) Auction choice. Mimeo, UCLA.

Maskin, E and Riley, J G (2000) Asymmetric auctions. *Review of Economic Studies*, **67**(3), 413–38.

Milgrom, P R (1979) A convergence theorem for competitive bidding with differential information. *Econometrica*, **47**, 679–88.

Milgrom, P R (1981) Rational expectations, information acquisition, and competitive bidding. *Econometrica*, **49**, 921–43.

Milgrom P R and Weber, R J (1982) A theory of auctions and competitive bidding. *Econometrica*, **50**(5), 1089–122.

Monteiro, P K and Moreira, H (2006) First price auctions without affiliation. *Economic Letters*, **91**, 1–7.

Myerson, R B (1981) Optimal auction design. *Mathematics of Operations Research*, **6**, 58–73.

Oren, S S and Rothkopf, M H (1975) Optimal bidding in sequential auctions. *Operations Research*, **23**, 1080–90.

Raftery, J (1991) *Principles of building economics*. BSP Professional Books.

Riley, J G and Samuelson, W F (1981) Optimal auctions. *American Economic Review*, **71**, 381–92.

Rothkopf, M H (1969) A model of rational competitive bidding. *Management Science*, **15**, 362–73.

Rothkopf, M H (1980a) On multiplicative bidding strategies. *Operations Research*, **28**, 570–5.

Rothkopf, M H (1980b) Equilibrium linear bidding strategies. *Operations Research*, **28**, 576–83.

Rothkopf, M H (1991) On auctions with withdrawable winning bids. *Marketing Science*, **10**, 40–57.

Rothkopf, M H and Harstad, R M (1994) Modeling competitive bidding: a critical essay. *Management Science*, **40**(3), 364–84.

Rothkopf, M H, Harstad, R M and Yuhong, F (2003) Is subsidizing inefficient bidders actually costly? *Management Science*, **49**, 71–84.

Runeson, G (2000) *Building economics*. Deakin: Deakin University Press.

Runeson, G and Skitmore, R M (1999) Tendering theory revisited. *Construction Management and Economics*, **17**(3), 285–96.

Skitmore, R M (1989) *Contract bidding in construction: strategic management and modelling*. Harlow: Longman Scientific and Technical.

Skitmore, R M (1991) The contract bidder homogeneity assumption: an empirical analysis. *Construction Management and Economics*, **9**(5), 403–29.

Skitmore, R M and Pemberton, J (1994) A multivariate approach to contract bidding mark-up strategies. *Journal of the Operations Research Society*, **45**(11), 1263–72.

Smith, B T and Case, J H (1975) Nash equilibria in sealed bid auctions. *Management Science*, **22**, 487–97.

Thaler, R H (1988) The winner's curse. *Journal of Economic Perspectives*, **2**, 191–202.

Vickrey, W (1961) Counterspeculation, auctions, and competitive sealed tenders. *Journal of Finance*, **16**, 8–37.

Wilson, R (1969) Competitive bidding with disparate information. *Management Science*, **15**, 446–8.

Wilson, R (1977) A bidding model of perfect competition. *Review of Economic Studies*, **44**, 511–18.

APPENDIX: FORMULAE FOR NUMERICAL ANALYSIS

Let bidders for an auction be indexed $i = 1,\ldots,n$ and assume each makes a bid

$$t_i = v_{1i} + v_{2i} s_i \tag{A.1}$$

where the cost estimate s_i is a realization of a random variable S_i with composite density $F(\lambda + \mu_i, \sigma_i)$ and v_{1i} and v_{2i} are the additive and multiplicative mark-ups respectively, λ is a parameter denoting the unique common value (nuisance) component of the auction (Skitmore 1991; Hong and Shum 2003), and μ and σ are the mean and variance unique to each bidder. Suppose each bidder knows only the values μ_j, σ_j, v_{1j} and v_{2j} for all $j = 1,\ldots,n$ bidders. Let θ denote the vector of all these values μ_j, σ_j, v_{1j} and v_{2j}. Now, the *expected profit* for bidder *i* is

$$E_{(k)i}[\theta] = P_{(1)i}(\theta)\left(E\left[T_{(k)} \middle| i \text{ wins}\right] - E\left[C_i \middle| i \text{ wins}\right]\right) \tag{A.2}$$

where

$$E\left[T_{(k)} \middle| i \text{ wins}\right] = \int_{-\infty}^{\infty} (v_{1i} + v_{2i}x) \frac{g_{(k)i}(x;\theta)}{P_{(k)i}(\theta)} dx \tag{A.3}$$

with

$$P_{(k)i}(\theta) = \int_{-\infty}^{\infty} g_{(k)i}(x;\theta) dx \tag{A.4}$$

where (k) denotes the *k*th lowest bidder. Assuming estimates are unconditionally unbiased (Flanagan and Norman 1985), the expected cost given *i* wins, $E\left[C_i \middle| i \text{ wins}\right] = \mu_i$.

The function $g_{(k)i}(x;\theta)$ depends on the composite density assumed. For the Uniform density, where $a_i = v_{1i} + v_{2i}(\mu_i - \sigma_i\sqrt{3})$ and $b_i = v_{1i} + v_{2i}(\mu_i + \sigma_i\sqrt{3})$, it can be shown that

$$g_{(1)i}(x;\theta) = \frac{1}{b_i - a_i} \prod_{j \neq i}^{n} \frac{b_j - x}{b_j - a_j} \quad (b \geq x \geq a) \tag{A.5}$$

and

$$g_{(2)i}(x;\theta) = \sum_{j_2 \neq i}^{n} \frac{1}{b_{j_2} - a_{j_2}} \frac{x - a_i}{b_i - a_i} \prod_{\substack{j_1 \neq i \\ j_1 \neq j_2}}^{n} \frac{b_{j_1} - x}{b_{j_1} - a_{j_1}} \quad (b \geq x \geq a) \tag{A.6}$$

for the FPA and SPA respectively.

Likewise, for the Normal density, letting $\mu_i' = v_{1i} + v_{2i}\mu_i$ and $\sigma_i' = v_{2i}\sigma_i$,

$$g_{(1)i}(x;\theta) = \frac{e^{-x^2/2}}{\sqrt{2\pi}} \prod_{j \neq i}^{n} \int_{\frac{\sigma_i' x + \mu_i' - \mu_j'}{\sigma_j'}}^{\infty} \frac{e^{-u^2/2}}{\sqrt{2\pi}} du \quad (\infty > x > -\infty) \tag{A.7}$$

and

$$g_{(2)i}(x) = \sum_{\substack{j_2=1 \\ j_2 \neq i}}^{n} \frac{e^{-\left(\frac{x-\mu'_{j_2}}{\sigma'_{j_2}\sqrt{2}}\right)^2}}{\sigma'_{j_2}\sqrt{2\pi}} \int_{-\infty}^{\frac{x-\mu'_i}{\sigma'_i}} \frac{e^{-u^2/2}}{\sqrt{2\pi}} du \prod_{\substack{j_1=1 \\ j_1 \neq i \\ j_1 \neq j_2}}^{n} \int_{\frac{x-\mu'_{j_1}}{\sigma'_{j_1}}}^{\infty} \frac{e^{-u^2/2}}{\sqrt{2\pi}} du \tag{A.8}$$

for the FPA and SPA respectively.

The optimal value of the mark-ups, v_{1i} and v_{2i}, are then obtained numerically by finding the values that maximize Equation A.2 for bidder *i*. (Note that s_i, although known, is not necessary for this calculation.) Repeating this procedure in turn for each bidder until convergence then enables the equilibrium mark-ups to be obtained.

HAS THE CONSTRUCTION INDUSTRY IMPROVED IN LAST 25 YEARS?

Heng Li[1]

Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong

Within the last 25 years, productivity in the manufacturing industry has improved by 10% on average annually in China and Japan; while the construction industry has only improved by 0.02% in China and slightly deceased in Japan. The question to be asked is why the construction industry has been so slow in productivity improvement. In this paper, I argue that the manufacturing industry possesses three critical successful factors (CSFs) that the construction industry lacks. I further argue that by adopting the construction virtual prototyping (CVP) technology, the construction industry can be equipped with the CSFs and make the same level of productivity and efficiency gain in the future. CVP is the use of integrated product, process and resource models of construction projects to support construction planning in a virtual environment. This paper describes an integrated framework and process for efficient application of CVP to support project teams on construction planning. It includes specific examples of models and objectives as well as detailed suggestions on how to implement CVP in practice.

Keywords: construction virtual prototyping, manufacturing industry, productivity improvement.

INTRODUCTION

It is generally agreed that the construction industry is lagging behind the manufacturing industry. However, it still appears to be surprising to compare the productivity data between these two industries. For example, Table 1 indicates that in Japan, while labour productivity in the manufacturing industry has been improved from 3531 in 1990 to 5131 (Yen/Man/Hour) in 2004, the value of the construction industry has dropped from 3714 to 2731 (Yen/Man/Hour) (JFCC 2006).

Table 1: Comparison of labour productivities in Japan (Unit: Yen/Man/Hour) (JFCC 2006)

Year	Manufacturing	Construction
1990	3531	3714
2004	5131	2731

A similar phenomenon is observable in China. According to the Ministry of Construction (MOC 2006), labour productivity of the manufacturing industry (RMB/Man/Hour) in

[1] bshengli@inet.polyu.edu.hk

China has improved from 24.4 in 2003 to 29.8 in 2008, while the construction industry has merely improved from 17.5 to 17.6, only managing to gain 0.5% improvement.

Table 2: Comparison of labour productivities in China (Unit: RMB/Man/Hour) (MOC 2006)

Year	Manufacturing	Construction
2003	24.4	17.5
2004	29.8	17.6

The reasons for such significant productivity-lag between the manufacturing and construction industries, in my view, are that the former has the following critical successful factors (CSFs), which the latter lacks:

- a well-defined production line in which products and parts, processes and logistics have been fine-tuned over a long period of time;
- the ability to predict risks and errors in design and production; and
- the ability to learn from mistakes and to avoid them in the future.

Although the use of prefabrication technology has indirectly introduced a production line into the construction project delivery process, the construction industry, by and large, does not have the ability to predict risks and errors. As a consequence, the construction industry is notoriously known to be very risky, and rework caused by errors in design and construction contributes up to 14% of the total construction cost (Li *et al*. 2000).

On the other hand, the construction industry lacks an effective platform to capture and reuse the knowledge distilled from its design and production processes. While the manufacturing industry builds and incrementally improves the productivity of the well-defined production line, the construction industry disbands the project team as soon as the project is completed. Except for the erected product, vast amounts of information and knowledge generated during the design and construction processes are often lost, or carried away by individual team members. Because of this, it is an open secret that often the same mistake recurs in future projects.

In this paper, I argue that the use of virtual prototyping (VP) technology can equip the construction industry with the second and third CSFs of the manufacturing industry. Specifically, I contend that VP technology enables the construction industry to predict and eliminate errors and risks in its design and construction processes; and the technology provides an effective platform to learn and reuse knowledge so that incremental improvement can be achieved.

Virtual prototyping (VP) is a computer-aided design process concerned with the construction of digital product models ('virtual prototypes') and realistic graphical simulations that address the broad issues of physical layout, operational concept, functional specifications and dynamics analysis under various operating environments (Pratt 1995; Xiang *et al*. 2004; Shen *et al*. 2005). Dedicated VP technology has been extensively and successfully applied to the automobile and aerospace fields (Choi and Chan 2004). However, the development and application of VP technology in the construction industry (i.e. construction process simulation) has been limited. This is probably because each construction project is unique in terms of the site conditions, requirements and constraints. Sarshar *et al*. (2004) identified three major industrial barriers to the uptake of VP technology, including cultural and risk issues related to information sharing, fragmentation of business interests and the lack of piloting on real construction projects.

The Construction Virtual Prototyping Laboratory (CVPL) at The Hong Kong Polytechnic University has applied VP technology to several real construction projects in Hong Kong. VP technology enables contractors to 'construct the building many times' in the computer. All sorts of scenarios can be previewed and potential problems identified in advance in this simulation process. The simulation process performs such tasks as the production, transportation, handling and assembly of different construction components, including all the associated operational processes. All the variables affecting the construction processes, such as site layout, plant locations, rate of machinery operation, quantities of resources, etc., can be considered in order to evaluate the feasibility of the proposed construction methods and sequences, and to explore possible solutions and improvements to the methodology prior to actual work beginning.

However, the VP technology is unfamiliar to contractors. Contractors expected but doubted the VP application on their projects in the beginning. General contractors and their planners often have little idea about how construction VP can help them. Some regard VP technology as only animation tools that represent their planning ideas more clearly. Although the new technology is useful to construction planning and project management, the misunderstanding of planners can be a major impediment for the adoption of the VP technology in the industry. In order to demonstrate the usefulness of the technology, researchers of the Construction Virtual Prototyping Lab at The Hong Kong Polytechnic University have worked very closely with contractors of several real life projects in Hong Kong. In fact, for each project, a researcher has been seconded to the site office to assist the planning and project monitoring process. Useful experiences and lessons have been drawn within the past two years, which will be reported in the subsequent sections of this paper.

3D/4D models support planners by relating building components from a 3D CAD system to construction activities from a project planning system, using a graphical interface. The construction process can then be simulated by executing the process modeller built in the simulation system and the user can visually check how the process proceeds. 4D CAD systems can be used for construction analysis and communication (de Vries and Harink 2007). Hartmann and Fischer [7] developed an integrated process of how project teams can use 3D/4D models efficiently to support the knowledge communication and generation needed during the constructability review on construction projects. Although 3D/4D models can help the planners to analyse the design, find out the collision and discover any missing or conversed sequence, the 4D process developed by Hartmann and Fischer emphasized the knowledge transfer to engineers or non-construction managers during the construction planning. This application is quite useful because efficient communication is the key factor of successful construction. But most of the time, verifying the appropriate construction method and making sure the construction schedule is feasible are the first issues of concern to the general contractor before transferring the planning knowledge. The experience from our research told us that the process of supporting the construction planning with the VP technology should assist planners to verify their planning as well as transfer their planning knowledge.

The application of the VP technology to the Ho Tung Lau project and the One Island East project in Hong Kong illustrate this effort well. A CVPL researcher (the first author of the paper) worked for one year on each project as part of the project team to support the VP modelling process and to assist the project team in resolving problems that arose during the preconstruction and construction stage. The aim of this paper is to describe an integrated framework and process for general contractors to successfully apply the CVP technology. This integrated process of how general contractors can use VP models to improve the construction planning practice is described first. This process can meet the different planning tasks in the preconstruction and construction stages by adjusting the content of VP models. Specific construction planning examples are presented to describe the adjusted content of VP models. The paper concludes with an overview of the opportunities and challenges for further application of CVP.

COMMON CONSTRUCTION PLANNING PROCESS

Construction project planning has been considered as a critical process in the early project phases that determines the successful implementation and delivery of a project. During this stage, project planners need to develop main construction strategies, to establish construction path and assembly sequences, to arrange construction methods and resources required for the execution of work packages, and even to write daily work instructions for field crews (Koo and Fischer 2000; Jaafari *et al*. 2001; Waly and Thabet 2002). The left part of Figure 1 is a diagram representing the process of construction planning. The planning process requires the transformation of information into analysis, decisions and actions. The general process of the VP models application is shown on the right side of Figure 1. Within this process, VP models support the knowledge generation and transformation at each of the planning steps.

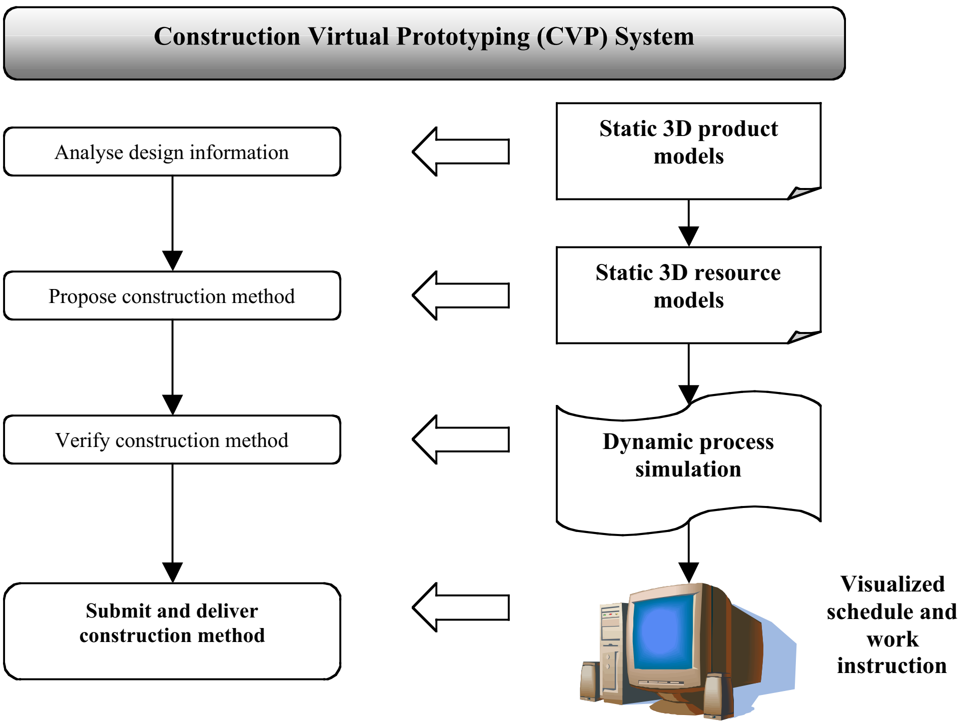


Figure 1: The integrated process of VP-supported construction planning

In the first step of the application process, static 3D product models are built to help the project team analyse and communicate design information. The design errors can be detected in 3D product models. The preparation of 3D product models also includes the modelling of the site environment, which can be used to study the site layout and review the constructability.

The second step is to build static 3D resource models including construction equipment and temporary works. Planners will propose some potential construction methods which may be suitable for the uniqueness of project design and construction site. Using the 3D resource models with the previous product models, the optional construction methods can be expressed in the virtual platform.

The third step is to simulate the construction process. The dynamic process simulation is a series of activities, each of which can have a defined duration, linked with construction components and resources (Figure 2). First, the abstract construction methods can be visualized by assigning the 3D product and resource models. Then the visualized methods can be tested and verified by integrating temporal and spatial considerations.

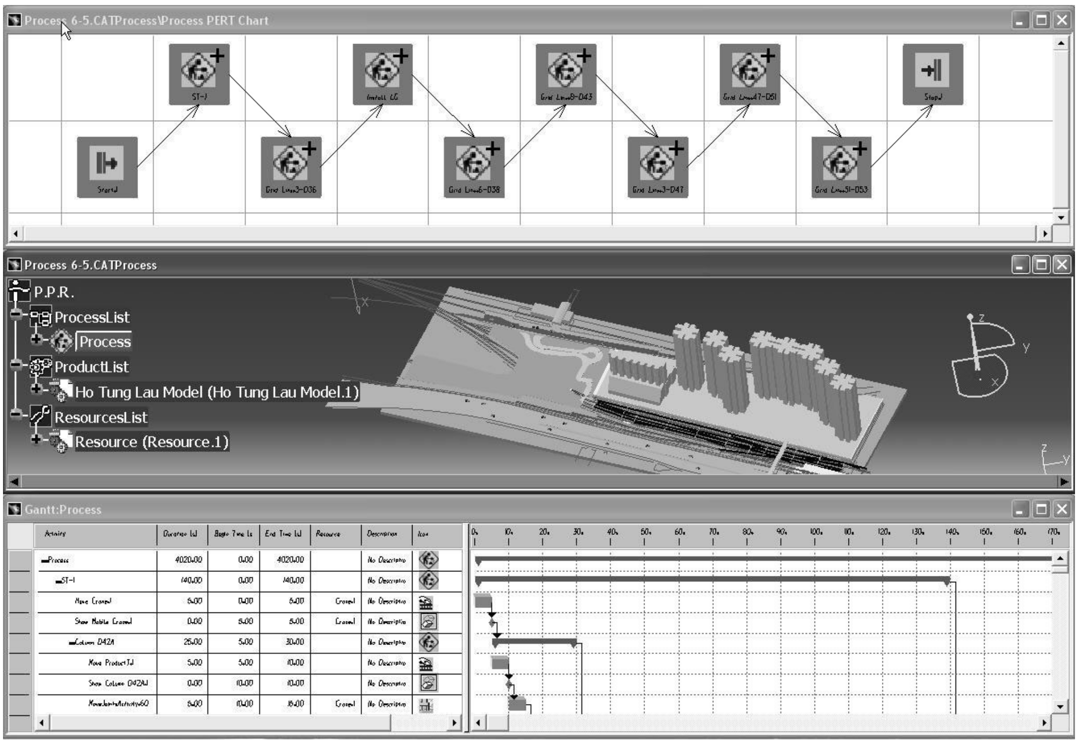


Figure 2: Integrated product, process and resource models of the construction project

In the final step of the construction planning process, the project team needs to submit or deliver the developed construction method to other participants such as project client, subcontractors and field crews. The visualized schedule and work instructions can help the construction planning to be effectively communicated and implemented.

The CVPL researcher’s experience on the several real construction projects shows that the above described integrated process effectively supported the construction planning of project teams. However, owing to the pressure of planning time, the timeliness of VP models is quite important for the efficiency and effectiveness of construction project management. VP models that require information cannot be built after the information is complete. Therefore, the content of VP models varies to satisfy the different stages of construction planning. The construction planning process is usually broken down into two stages: macro and micro planning processes [8]. Although the main process of the planning is the same, the tasks of the planning are different. During the preconstruction stage, the macro planning process involves reviewing the design for constructability improvement, selecting major construction methods and resources, and planning site layout. During the construction stage, the micro planning process develops detailed schedules to instruct the day-to-day operation. The above integrated process in Figure 1 can meet the different planning tasks in the preconstruction and construction stages by adjusting the content of VP models. In the following section, we will describe the content of VP models for different construction planning stages with specific examples. The detailed approach for 3D modelling and process simulation are not covered in this paper and can be found in Huang *et al*. (2007).

THE CONTENT OF VP MODELS

Construction planning case

The Ho Tung Lau project is to construct a deck to be situated above existing buildings by the general contractor. In part of the deck area, the confined site of the works is covered by live track and high voltage overhead cables, portal frames and many other railway facilities and furniture. The structures in this area comprise composite columns, heavy steel truss (weight approx. 285 ton), steel girders (approx. weight 80–100 ton) and precast T-beams spanning between steel girders for decking. Apart from the weight and length of the steel structure, the alignment of the building line varies owing to the existing configuration of Tai Po Road and the level of deck. There is a footbridge at high level over the site of the work. Two portal frames for overhead cables also run across over the entire working area. Other than those as mentioned above, all the works must be carried out during isolated sessions, that is between the times of 11.00 and 16.00. The site work must be cleared and released back to the railway company without any delay at the end of each isolated session.

In this project, the railway safety is of paramount importance; any untoward incident might jeopardize the railway services, which could result in potential claims for damages from the railway company due to delays in train services. Therefore the railway safety, the time periods allowed for construction and the suitability of the method adopted for construction of such steel frames are the major considerations in the selection of the proper method for construction of superstructure works in this work area. The VP technology is applied to support the contractor in selection and verification of the appropriate construction method. The following subsection will describe the content of VP models for the product modelling process, the resource modelling process, method simulation process, and method submission process in the construction planning stage.

3D product model supported analysis of design process

Before proposing the construction method, the planners will analyse the project design and site environment. So the 3D models of product model and site model can provide a virtual experiment platform to review the design, select the construction equipment and method, plan the site layout, and verify the safety issues, etc.

Construction components modelling

To select the construction equipment and method, the project team will review the design drawings and break down the building or facility into major components such as columns, beams, slabs and walls. The 3D component models, on which attributes such as length, volume and weight can be directly measured, can assist planners to study how these components will be built and controlled on site.

In this project, the 3D models of steel columns, steel girders, steel trusses, and precast T-beams are built according to the drawings in the first step. Then the structure components are assembled to the podium (Figure 3(a)). In this step, design error can be identified in the early construction stage. This is especially useful for the contractor if the project's delivery method is design and build. The 3D models can also provide information such as volume, weight and quantity of components to assist the planners in analysing the design.

Site modelling
In Hong Kong, the construction site is quite confined. Site investigation usually occurs at the beginning of the project and includes major issues such as site access and planning [8]. In this example, the construction site is on the live track. The high voltage overhead cables are irregularly distributed on site. The movement of construction equipment is prone to damage the cables. The site survey information was used to build the site model. The models of damageable facilities on site were built in the 3D model, such as the rail line, power cable and cable portal. The models of site boundary, surrounding buildings, site entrance and road were built as these factors may become a constraint while planning. The 3D models can be quickly built because the profiles of the site facilities are usually enough for the planning (Figure 3(b)). The safety zone of the facilities was also added by researchers because the bound of the safety zone is larger than the facility itself and cannot be occupied or intruded upon. The site model is assembled with the 3D product model built in the first step.

The static 3D product model and site model can help the planners to analyse the site constraints, identify the potential problems and plan some possible construction methods.

3D resource model supported proposal of construction method process
Construction equipment modelling
Construction methods are determined by the building products and the construction equipment. After reviewing the design and site survey information, the planners will find some possible construction equipment which is thought to be suitable to the construction product and site. Construction equipment's installation, dismantlement, site layout, loading limit and space requirements while moving are the sorts of concerns in the planning. So, the next step of VP modelling is the construction equipment modelling.

For this project, planners wanted to compare three kinds of possible construction equipment including the mobile crane, mobile gantry and launching girder (Figure 3(c)). At this stage, they usually have not the detail of the design or type of equipment. Planners will draft the profile of equipment and describe the mechanism of main parts. This rough information is used to build the construction equipment model. To put them into the virtual platform, planners will have explicit clues to planning the construction method. With the development of planning, more information can be provided to build the equipment model with detailed attributes.

Temporary works modelling
The temporary works usually cost a large part of any contract. Failure in planning appropriate temporary works affects safety, quality and productivity adversely (Chini and Genauer 1997). At the preconstruction stage, the approximate shape and the location of temporary works will be used to build the temporary works and assemble them into the model. This qualitative visualization will help the planners to think their planning method more clearly. In this project, the temporary works are difficult to set up owing to the protected area for the railway and the power cables. Planners can review the location of temporary works in this virtual environment (Figure 3(d)).

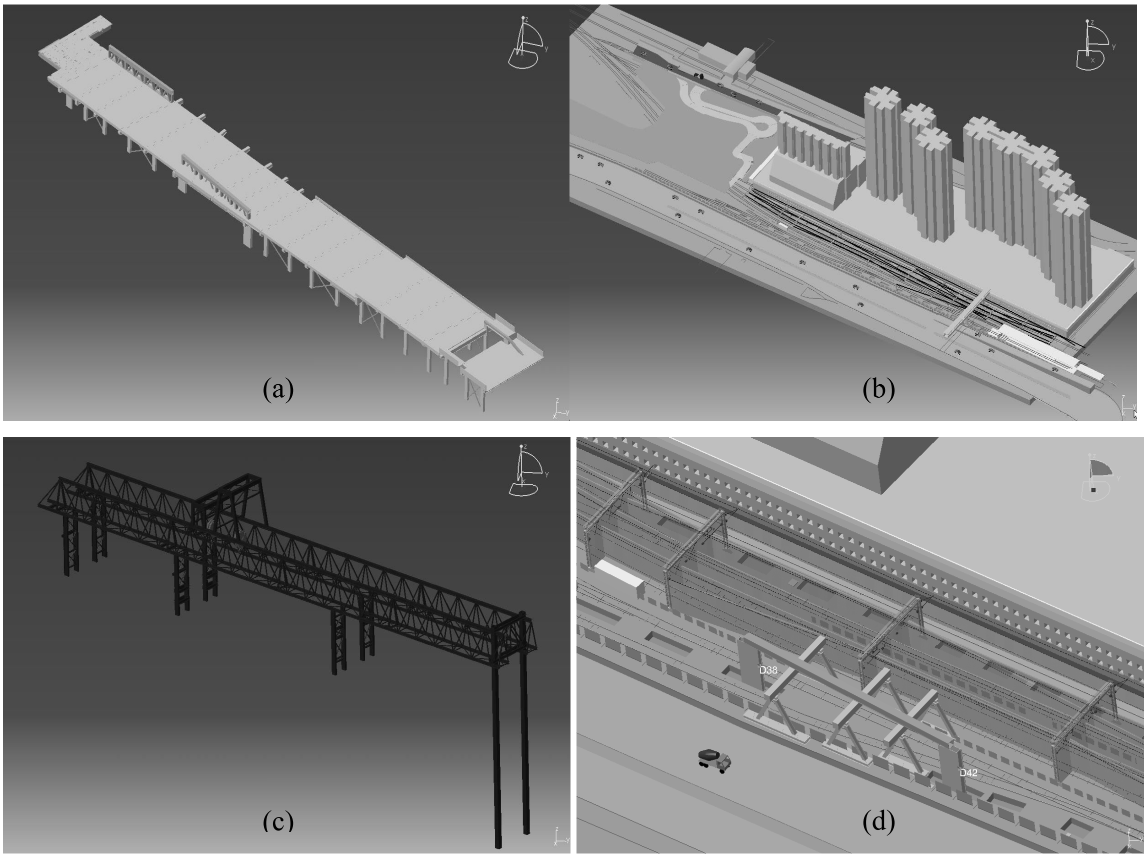


Figure 3: 3D product and resource models of Ho Tung Lau project

Construction method simulation and selection

Construction method visualization

In a traditional planning process, planners need to construct a 3D mental model of the construction project by mentally integrating 2D drawings, CPM-based schedules and other information. This is largely an experience-based process, thus more experienced planners often construct more comprehensive mental models and therefore generate better construction plans. The VP technology overcomes this weakness as it provides a platform to visually simulate the construction process including all 3D models of the design, the site environment and the resources to be used in the project. The simulation can not only provide the same level of understanding to all project participants, but also facilitate effective communication between them. More importantly, the simulation model provides an inexpensive and safe platform for project participants to evaluate different construction methods and identify possible risks and problems.

To develop the VP simulation model, the following information is needed:

- What construction equipment is used for specific components and how does it operate?
- How are the construction components installed and what is the installation sequence?
- What kind of temporary works are needed and where to install them?

With the above information and 3D models of the design and site environment, the construction project can be digitally represented and its processes digitally simulated and evaluated.

Method verification process
Virtual prototyping technology can help planners to study every step of the construction activities by running through the whole construction process in the simulation system. If problems are found, planners need to propose remedial actions and then re-run the simulation process to verify if the proposed remedial actions are workable. This trial and error process continues until the whole construction process is evaluated. Thus, with the use of VP technology, most construction risks and problems can be identified and solved before the commencement of the project.

In the Ho Tung Lau project, the launching girder method was identified and selected as the most appropriate construction method. After selection of the construction method, planners must ensure the safe and smooth operation of the railway line and the power cable by using the detailed, step-by-step, simulation of the construction process. During this simulation, many problems were identified and corrective measures were taken. Figure 4 shows some examples of identified problems such as installation beyond the site boundary and equipment athwart the power cable. After going through the whole project, the contractor has gained sufficient confidence of the selected construction method.

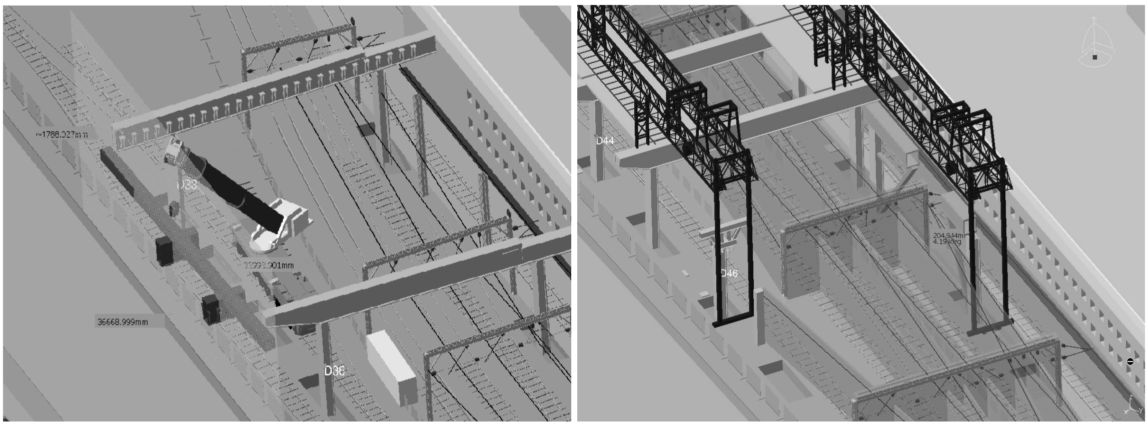


Figure 4: Identified problems during the method verification process

Visualization of construction process as a communication tool between client and contractor
Once the simulation is completed, it can used for many purposes. For example, as the simulation visually presents the construction process, it can be easily understood by the client. In the Ho Tung Lau project, with the help of the simulation model, the project team persuaded the railway company to extend the working hours on some days, in order to complete certain important construction tasks. The project has been completed on time within budget. After completion, both the client and the contractor admitted that it would not have been possible without the use of virtual prototyping technology.

Detail method simulation and delivery

Working space visualization

In the detailed planning process, planners need to optimize the time and resource use based on the master programme. The detail method can be developed to provide work instructions to crews. The working space is an important factor affecting the efficiency of construction work. Planners must develop the detail method and schedule according to the working space. However, it is difficult for planners to image the working space in a mental model. In addition, once the construction joint or the location of the construction equipment is changed, the working space will be different. The VP technology can help planners to visualize the available working space and to develop the detail method. The following further information is needed:

- the location of construction equipment while operating;
- the quantity and size of construction components being installed;
- the size of temporary works needed.

With the above information and visualized construction method, the detailed sequence of activities can be digitally developed and their durations digitally estimated and evaluated based on the available working space.

Visualization of work instructions from general contractor to subcontractors

It is hard for a complex schedule to be understood and implemented by many subcontractors and field crews. At the construction stage, a learning period for field crews is often required. The effective work instruction will shorten this learning period. The pictures extracted from the VP model were used to give subcontractors and field crews visualized work instructions (Figure 5). The project team found that the visualized work instructions can be understood more easily than only oral instructions.

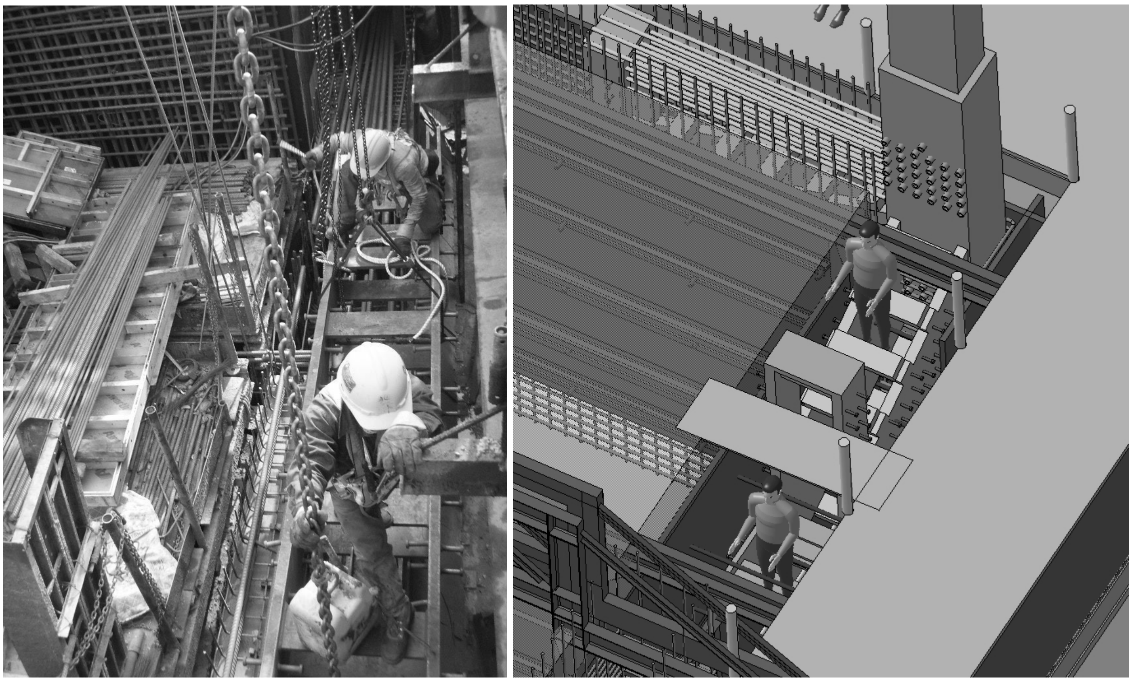


Figure 5: Visualized work instruction versus the real installation

CONCLUSIONS

So, has the construction industry improved within last 25 years? The answer is probably 'yes', but the improvement is less visible than that in the manufacturing industry. This paper argues that through using VP technology, the essence of the manufacturing industry can be learnt and transplanted into the construction industry. The development and application of the virtual prototyping (VP) technology in the construction industry is still relatively new. This paper describes an integrated framework and process for general contractors to apply the VP technology. The process described in this paper can assist planners to verify their plans so that construction risks can eliminated before the commencement of the project.

The benefits of using VP can be summarized as follows:

- the creation, analysis and optimization of construction schedules;
- effective constructability analysis;
- elimination of construction risks through digital mock-up of processes;
- clearer understanding of project scope and better work instructions from general contractor to subcontractors;
- effective communication between the client and contractors;
- effective management of design changes; and
- better capture and reuse of knowledge.

With the use of VP technology, it is now possible to conduct a digital mock-up of the entire construction process so that construction risks can be identified and eliminated. By capturing knowledge gathered during the design and construction stages, it is possible for construction organizations to learn and accumulate knowledge, and this will lead to incremental productivity improvement. Ultimately, the use of VP technology can potentially revolutionize the construction industry.

ACKNOWLEDGEMENTS

Funding for data collection and analysis was supplied through the Research Grants Council of Hong Kong through allocation from the Competitive Earmarked Research Grant for 2005/06 under Grant Number PolyU5103/05E. The research has also been supported by another Competitive Earmarked Research Grant for 2005/06 under Grant Number PolyU5209/05E. I wish to thank Professor Andrew Baldwin, Tim Huang, H L Guo, Neo Chan, Jack Chung and Stephen Kong for their contribution to the work presented in this paper. I wish also to thank Professor Peter Brandon for sharing his vision with us.

REFERENCES

Chini, A and Genauer, G (1997) Technical guidance available to designers of temporary structures. Paper presented at the American Society of Civil Engineers Fifteenth Structures Congress, Portland, OR.

Choi, S H and Chan, A M M (2004) A virtual prototyping system for rapid product development. *Computer-Aided Design*, **36**, 401–12.

De Vries, B and Harink, M J (2007) Generation of a construction planning from a 3D CAD model. *Automation in Construction*, **16**, 13–18.

Hartmann, T and Fischer, M (2007) Supporting the constructability review with 3D/4D models. *Building Research & Information*, **35**(1), 70–80.

Huang, T, Kong, C W, Guo, H L, Baldwin, A and Li, H (2007) A virtual prototyping system for simulating construction processes. *Automation in Construction*, doi:10.1016/j.autcon.2006.09.007.

Jaafari, A, Manivong, K K and Chaaya, M (2001) Interactive system for teaching construction management. *Journal of Construction Engineering and Management*, **127**(3), 66–75.

JFCC (Japan Federation of Construction Contractors) (2006) *2006 Construction industry handbook*.

Koo, B and Fischer, M (2000) Feasibility study of 4D CAD in commercial construction. *Journal of Construction Engineering and Management*, **126**(4), 251–60.

Li, H, Love, P and Drew, D S (2000) The effect of project delays on project cost, quality and rework. *Engineering, Construction, Architecture Management*, **7**(3), 211–20.

MOC (Ministry of Construction) (2006) *Construction year book 2006*. PR China.

Pratt, M J (1995) Virtual prototyping and product models in mechanical engineering. *In*: J Rix, S Haas and J Teixeira (Eds.) *Virtual prototyping: virtual environments and the product design process*. London: Chapman and Hall.

Sarshar, M, Christiansson, P and Winter, J (2004) Towards virtual prototyping in the construction industry: the case study of the DIVERCITY project. *In*: *Proceedings of the World IT Conference for Design and Construction*, 18–24 February 2004, Langkawi, Malaysia, 581–8.

Shen, Q, Gausemeier, J, Bauch, J and Radkowski, R (2005) A cooperative virtual prototyping system for mechatronic solution elements based assembly. *Advanced Engineering Informatics*, **19**, 169–77.

Waly, A F and Thabet, Y W (2002) A virtual construction environment for preconstruction planning. *Automation in Construction*, **12**, 139–54.

Xiang, W, Fok, S C and Thimm, G (2004) Agent-based composable simulation for virtual prototyping of fluid power system. *Computers in Industry*, **54**, 237–51.

INTEGRATION OF THE HUMAN RESOURCE MANAGEMENT FUNCTION INTO LARGE CONSTRUCTION COMPANIES OPERATING IN GHANA

Lily Sena Agbodjah[1], Andrew R J Dainty[2] and Theophilous Adjei-Kumi[1]

[1]*Department of Building Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[2]*Department of Civil and Building Engineering, Loughborough University, Leicestershire LE11 3TU, UK*

In order to be successful in competitive markets, construction companies need to adopt appropriate people management practices that support their business strategies. The nature and characteristics of the construction industry poses some difficulties for companies in strategizing for their human resource management (HRM) policies and practices. The research reported in this paper examined how the HRM function has been integrated into construction companies operating in Ghana. Descriptive and content analysis methods are employed in examining how these organizations align their HRM practices with their strategic goals. The investigation revealed that in most companies the function is generally regarded as a cost burden and has little strategic influence. Line managers are not equipped with the requisite skills to enable them manage people effectively and they are not generally supported with a robust HR infrastructure to oversee people management strategy at the centre of the business. It is recommended that Ghanaian construction companies should employ specialist personnel to undertake this function or employ the services of HRM Consultants to aid in structuring their people function in such a way as to align with their business objectives.

Keywords: strategic management, human resource management, integration, developing country, Ghana.

INTRODUCTION

The ability to attract, retain and develop talented employees is a key feature of a successful business (Eddy 1981). People management has over the years evolved in the bid to enhance individual and organizational growth and viability of businesses. Some conceptual developments have contributed by enhancing the effects of people management in organizational development and success. These have resulted in the concept of strategic HRM (Armstrong, 2001; Loosemore *et al*. 2003). Strategic HRM is concerned with integrating the HR function advantageously into the functions of an organization for corporate competitive advantage (Armstrong 2001). It is basically concerned with both meeting the human capital needs of an organization and the development of process capabilities. It focuses on actions that differentiate a company from its competitors. There is the need therefore to ensure that the HR function is effectively integrated both vertically (into the overall business strategies of the

[1] sagbodjah.cap@knust.edu.gh

organization), and horizontally (in terms of ensuring the compatibility of the various HRM dimensions) within an organization (Armstrong 2001).

The concept of people management has evolved in the construction industry like other industrial sectors. However, the peculiar characteristics of this industrial sector: fragmented nature; unique, one-off nature of products; reliance on transient workforce, increasingly demanding clients amongst other, has rendered managing people a great challenge to practitioners and researchers alike (Druker *et al*. 1996; Egan 1998; Langford *et al*. 1995; Loosemore *et al*. 2003). This has rendered the efficacy of HRM practices within the construction industry questionable. From a preliminary survey conducted prior to this research, it was realized that research in the subject matter in the Ghanaian construction industry is on a low scale. Also construction companies regard this function as a liability instead of an asset to ensure organizational competitiveness and success.

Huselid *et al*. (1997) noted that existing HRM practices have been shaped by institutional environments of the countries in which companies originate from. Practitioners adopt models and theories made to suit the developed world with little or no consideration to the characteristics of companies in developing economies and resource availability. These models are considered as benchmarks for measurement of performance, productivity and even how some functions should operate. It is in this vain that this research is carried out to investigate how the HR function has been strategically integrated into construction companies operating in Ghana. The paper provides a brief overview of the nature of the Ghanaian industry and the structure of construction companies within the sector. Further the role of the HRM function within companies will be investigated and recommend an appropriate integration of the HR function within these companies considering their peculiar characteristics.

THE GHANAIAN CONSTRUCTION INDUSTRY

The Ghanaian construction industry accounts for a sizeable proportion of the nation's economic and developmental growth (approximately 10% of GDP). In the 2006 national budget, the industry recorded a 7.0% growth whereas its contribution to the overall economic growth stood at 9.8% (The National Budget 2006). It is described as diverse, complex and dynamic industry with increasing uncertainties with regards to technological developments, the national budget and resource availability. Companies operate in a constantly changing environment in the face of volatile economic environment, shifting political climate and a highly competitive market (Dansoh 2004).

History

The industry was developed along lines similar to the pattern in Britain where the bricklayers acted as master builders in project delivery. It has since developed into two sectors: the formal and informal sectors. The latter adopts an approach similar to this historical approach of master craftsman engaging labour in product delivery (Miles and Ward 1991; Mlinga and Wells 2002; Wells 2001; Wells and Wall 2003). In 1886, the British established the Public Works Department to formally oversee construction works in the then Gold Coast, now Ghana. Political independence in 1957 saw to the establishment of the Ghana Highway Authority, the defunct State Construction Corporation and the Architectural and Engineering Services Limited to take over the formal construction sector. The advent of sophistication brought into being the establishment of other state departments as well as private organizations

(Osei-Asante 2005). Developments in the formal sector has however resulted in the adoption of a variety of procurement systems regulated by the Public Procurement Act 2003, Act 663 of the Republic of Ghana (Anvuur and Kumaraswamy 2006)

Structures

Construction companies operating in Ghana register with the Registrar General Department (RGD) as limited liability companies and the Ministry of Water Resources, Works and Housing (MWRWH) and/or the Ministry of Road Transport (MRT) for building and civil engineering works respectively. The Government of Ghana (GoG) has always been the major client funding public sector projects at the District, Metropolitan/Municipal, Regional and National levels (MWRWH and MRT archives). The MWRWH has four categories of companies based on the nature of work they engage in (Ministry of Water Resources Works and Housing, 2004). These are categories D, K, E and G for building, civil engineering, electrical and plumbing works respectively. There are four financial sub-classifications within these categories: 1, 2, 3 and 4 (Appendix 2b). These classifications set the limitations for companies in the respect of their asset, plant and labour holdings (Appendix 1) as well as the nature and size of projects they can undertake. Class 1 companies are large companies by local standards and decreases in resource and asset base through to 4 (Ministry of Water Resources Works and Housing, 2004).

STRATEGIC HUMAN RESOURCE MANAGEMENT

Morley (2004) describes the two core assumptions underlining classical North American HRM models from a comparison of European and North American HRM ideologies in a paper by Chris Brewster. First is the broadly universalist ideology where prescriptions are intended to be workable and applicable in all different circumstances. This applicability, he argues, springs from several sources including managerial discretion and attitude, State *laissez-faire*dom in business and a comparatively weak trade union movement. The second is the involvement of HRM with business strategy. This looks holistically at the business strategy of the organization and how the HRM function can be integrated strategically for a competitive advantage (Morley 2004).

Armstrong (2001) defined Strategic HRM as a term that describes an integrated approach to the development of strategies which will enable the organization achieve its goals. He further described it as an approach to making decisions on the intentions and plans of the organization concerning employment relationship as well as their recruitment, training, development, performance management, reward and employee relations strategies, policies and practices. This he said is linked to the concept of strategy which is defined by Johnson and Scholes (1993) as the direction and scope of an organization over the longer term, which ideally matches its resources to its changing environment, and in particular to its markets, customers and clients to meet stakeholder expectation (Armstrong 2001; Johnson and Scholes 1993).

The HR strategy is integrated in two dimensions: vertically to the business strategy of the organization and horizontally to each other. Armstrong (2001) outlined three basic approaches of attaining this integration as the ‘best practice’, the ‘best fit’ and the ‘configurational’ or ‘bundling’ approach. These approaches help to develop HR strategies that will generate strategic capability by ensuring that the organization has the skilled, committed and well-motivated employees it needs to achieve sustained competitive advantage (Armstrong 2001). There is a broad agreement that a strategic approach to HRM involves designing and implementing a set of internally consistent policies and practices that ensure a firm's human capital (employees' collective knowledge, skills and abilities) contributions to the achievement of its business objectives (Huselid *et al*. 1997).

Strategic HRM has not come without limitations. Armstrong (2001) acknowledged these limitations by recording that; strategic HRM appears to be based on the belief that the formulation of strategy is a rational and linear process. This he said is not the case in reality. In this same light, Mintzberg (1987) emphasized that strategies emerge overtime in response to evolving situations. Tyson (1997) agreed by stating that strategic HRM is always 'about to be' and never existent in the present time (Armstrong 2001; Mintzberg 1987; Tyson 1997). Huselid *et al*. (1997) also concluded after an empirical study that there is evidence that fundamental to the strategic HRM perspective is the assumption that company performance is influenced by the set of HRM practices the company has in place.

The question then is how can strategic integration be achieved? More so in a developing economy. Baldocchino (2001) argued in his paper that small territories, and indeed developing economies, have often blindly accepted an 'industrial relations' (IR) framework that is much more at home in the formalistic, mass production and mass employment based manufacturing economies of the industrialized world. He further added that while IR in these settings is also being called into question today, small territories have been hard put all along to apply their labour relations practice to the structures of these theories (Baldacchino 2001).

Huselid *et al*. (1997) also noted that existing HRM practices have been shaped by institutional environments of the countries in which companies originate from. Practitioners adopt models and theories made to suit the developed world with little or no consideration to the characteristics as well as available resources of companies in developing economies. These models are considered as benchmarks for measurement of performance, productivity and even how certain functions should be operated. This has necessitated this investigation, which seeks to find out how construction companies operating in Ghana integrate the HR function into their businesses and recommends an appropriate integration of the HR function within these.

PURPOSE OF INVESTIGATION

Scholars have over the years developed various HRM models which have been developed from researches in North America and in Europe (Hall 2004). A lot of work has also been undertaken in the area of strategic HRM, the approach in vogue. However, these do not give a cross-national picture in the wake of globalization and internationalization of businesses. Budhwar and Sparrow (2002) in a bid to address this, developed an integrated framework which delineates the main distinctive facets associated with national factors, contingent variables and organizational and HR strategies and policies that may be used to evaluate cross-national comparative HRM policies and practices (Budhwar and Sparrow 2002). Under the dynamic business conditions of this age as well as the difference in culture and characteristics of organization, relevance of lessons learnt from the European and Northern American experience of HRM is questionable if adopted holistically for other economic, geographic and cultural settings. Budhwar and Sparrow (2002) further sets the platform for global investigations into the HRM practices of various industries within particular national and cultural contexts. This has necessitated investigation into how this all-important function has been strategically integrated into the function of construction companies within the Ghanaian construction industry as well as the role it plays in the overall function of these companies. Such an investigation will enable the development of recommendations for ensuring the appropriate strategic integration of this function within construction companies operating in Ghana.

METHOD OF INVESTIGATION

This paper presents the results of a survey conducted in 2005/6, which is part of research being conducted at the Kwame Nkrumah University of Science and Technology (KNUST). This research aims at providing a tool to enhance people management in large construction companies operating in Ghana. The questionnaire developed and used, comprised three sections that sought to investigate the characteristics of companies, their human resource management practices, the role this function plays in the company and their policies. These were supplemented with a set of semi-structured interviews to further examine their HRM practices and policies. Building and Civil Engineering companies registered with the Association of Building and Civil Engineering Contractors of Ghana (ABCECG) as of 2005 were employed as the sample. Forty-nine large companies (Appendix 2a) were adopted as the population for the survey. By employing the Kish formulae, a minimum sample size of 36 was obtained (Barbbie 1995; Kish 1965). Companies were selected by employing stratified and random sampling methods. The regional divisions of the country, 10 in number, were adopted as the strata criteria. By the use of ratios, the strata sample sizes was determined. The companies were thus selected randomly within the various strata. This provided a fair sample representation across the entire country. The data obtained from the survey was analysed by employing descriptive analysis methods with content analysis methods adopted for the analysis of the semi-structured interviews. These methods were selected due to the focus of the instruments which required that the content of the data be analysed to identify key themes, trends, concepts and categories (Easterby-Smith *et al*. 1991). A frame was thus designed with the key concepts and themes on the horizontal axis and the responses from the individual companies on the vertical axis. The trends, themes, concepts and categories, were thus identified for analysing the content of the data.

RESULTS

The questionnaire was administered to 36 companies though only 28 were interviewed. After analysis, it was realized that companies could be grouped into two basic categories based on their origin: foreign and local ownership. There is, however, a third category, which is a partnership between these two basic categories. Local companies are owned by indigenous Ghanaians. Nine of the twenty-six employed in the survey are owned by sole proprietors. Six are in some form of partnership with the remaining eleven being limited liability companies with the board of directors comprising members of a nuclear family. The foreign companies are mainly subsidiaries of an international company hence represented locally by a representative who builds a management team. In addition, companies owned by foreigners living in Ghana are categorized as foreign companies since their practices are similar. As the name depicts, partnership companies are a partnership between local and foreign companies. The results of the entire survey are presented by capturing concepts identified by virtue of the method of analysis adopted. This includes how companies are managed, the nature of the HR function within companies and the role of the HRM departments in the company.

CHARACTERISTICS OF THE HRM FUNCTION, DEPARTMENT AND PERSONNEL

Construction companies operating in Ghana have specific characteristics and cultures due to the peculiarity of the industry and their origins. Management of companies is mainly centralized with the Managing Director (MD) or Chief Executive Officer (CEO) responsible for all major administrative and technical decisions. Artisans and labourers are not considered in general decision making though technical professionals are to some extent considered in technical decision making. Figure 1 shows a typical organizational structure of a construction company operating in Ghana. The levels range between four and eight depending on the number of professionals the company employs and its operational methods. Comparing Table 1 and Figure 1, the level of the personnel in charge of the HR function can be identified.

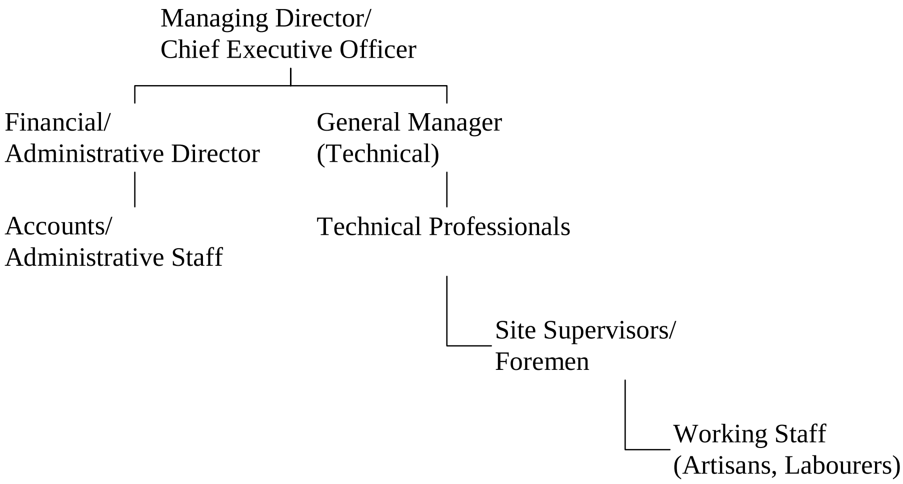


Figure 1: Typical organizational structure of construction companies operating in Ghana

Table 1: Characteristics of HRM function and department

Category of Company	HRM Dept.		Name of Dept.				Who is in Charge of HR function					Nature of Function		
	Yes	**No**	**HR Dept**	**H Rel. Dept**	**PD**	**F/A**	**HR Mgr**	**PM**	**MD**	**GM**	**F/A D**	**CA**	**MP**	**C**
Local	9	17		1	5	3	1	4	9	5	7	4	14	8
Foreign	8	1		1	6	1		4	2	2	1	3	1	5
Partnership	1		1				1							1
Total No.	18	18	1	2	11	4	2	8	11	7	8	7	15	14

KEY

HR D - Human Resource Department
H Rel. D - Human Relations Dept.
PD - Personnel Department
HR Mgr - Human Resource Manager
PM - Personnel Manager
MD - Managing Director
GM - General Manager
CA - Collective Agreement
MP - Management Prerogative
C - Combination of CA and MP
F/A - Financial/ Administrative
Dept. - Department

HRM personnel

The personnel in charge of the HRM function in companies are not necessarily directly in touch with the workforce and vary from company to company. The workforce does not necessarily have access to these personnel. This is contrary to HRM literature, which promotes line managers being in charge of some HRM functions to allow for an effective horizontal integration. These personnel are mainly technical experts with little or no HRM training to equip them with the requisite people management skills. In most cases (Table 1), the MD or the General Manager (GM) is in charge of this function. In this case, the HRM needs of the organization are integrated into the overall business goals. This is not to imply that in cases where there is an HR or Personnel Manager, the function is not integrated into the organization. In the foreign and partnership companies who employed the services of these personnel, their job description allows them to contribute in strategizing for the business allowing for integration into the overall business strategy of the company.

Table 2: Roles of department responsible for the HRM function

Category of Company	Role of Department Responsible for HRM Function							
	Business Partner	Strategist	Interventionist	Innovative	Internal Consultancy	Monitoring	Proactive	Reactive
Local	3	4	2	3	2	7	2	1
Foreign	2	1	4	2	3	5	3	2
Partnership	1	1	1	1	1	1	1	1
Total No	6	6	7	6	6	13	6	4

HRM departments

Of interest to the research is the rather lackadaisical attitude of the industry as a whole towards the HRM function. It is interesting to note that the MWRWH in their guidelines do not make the existence of an HRM Personnel in companies a requirement resulting in the reluctance of organizations to employ professionals or train existing employees to take up this responsibility. Thus, this function is regarded more as a liable cost rather than an asset to organizations. Half the number of the surveyed companies' recorded that they have a department responsible for the execution of the function though they dubbed it differently (Table 1). The interview revealed that these departments exist more as Personnel Departments concerned with IR, handling legal people issues and workplace conflict management but not involved with the business of companies. A few however listed their roles to include the business partner role, the strategist role, the interventionist role, the innovative role, the internal consultant role, the monitoring role and the proactive and reactive roles (read more in Armstrong (2001) Chapter 5) the frequencies of which are in Table 2. These do not allow for the needed horizontal integration necessary to provide the organization with the needed competitive advantage.

The HRM function

The HRM function is mainly executed by management prerogative. That is to say, HR decisions are taken by management and implemented with no consultations with the general workforce. Fourteen out of the twenty-six local and one foreign company relied mainly on this system. Due to the non-existence of explicit HR policies, companies rely mainly on the Collective Agreement of the ABCECG and the Construction and Building Materials Workers Union of the Trade Union Congress (CBMWU of TUC) which is the dominant employee organization for construction workers in the industry. Four local and three foreign companies manage people by solely employing this document. Eight local, five foreign and the partnership company combine management prerogative and the collective agreement (Table 1).

DISCUSSION

The investigation reveals that not all companies (50%) have specific departments responsible for the execution of the HRM function. In fact, the personnel responsible for HR tend to be allocated this task irrespective of whether or not they have had some training in people management (Table 1). The availability of cheap and abundant labour does not also impress the need for appropriate people management practices to ensure staff retention. Cost, time and quality requirements of projects have however resulted in the need for more committed employees with the requisite skills. Further, the influx of international contractors and the need of other industrial sectors for construction professionals have increased competition for competent employees. This has prompted the need for adequate people management.

Overall, construction companies in Ghana lack well-structured and well-defined organizational structures. This makes it difficult for them to develop well-defined business strategies found in other industries such as financial and manufacturing. Also the nature of the industry does not allow for long-term planning making it difficult for companies to clearly outline their strategies. Most decisions are impromptu, policies are ad hoc and there is seemingly little formal planning underpinning them. The nature of employment (mainly casuals), the outsourcing of jobs and companies not having project security also adds to the instability in the industry.

The role of the department responsible for people management and the level of the personnel in charge of this function in the company has a great impact on how well integrated this function is in the light of all these instabilities. This gives rise to the two perspectives of the HR function: from the HR perspective and the business strategy perspective. Both vertical and horizontal integration of this with the business strategy of the organization will be discussed.

Vertical integration of HR function into company business strategies

Vertical integration is concerned with achieving strategic integration of HR strategies with business strategy. This is to ensure that the company has the skilled, committed and well motivated workforce it needs to achieve its business objectives (Armstrong 2001). The absence of a business strategy impairs the attainment of a vertical integration. Large construction companies within the Ghanaian construction industry, according to the MWRWH guidelines should have a financial ceiling of over five hundred thousand US dollars for a three-year period (Ministry of Water Resources Works and Housing 2004). In spite of this, some 30% of local companies find their turnover to be less than this figure. Local companies have an average of 16 professionals, foreign companies, 39 professionals and the Partnership Company, 19 professionals who are mainly technical staff. Companies reported that it is uneconomical to keep these professionals on when there are no ongoing projects, which is a regular experience especially for the local companies. A mere ten of the entire population had personnel trained in people management employed. It was generally believed that it is woefully uneconomical employing these professionals. The sizes and financial bases of companies make it uneconomical to employ personnel trained in people management. Further, due to high labour turn over which is as a result of poor conditions, companies fear to train other professionals to adequately strategize to integrate the HR function into the business strategy of the organization.

The advantage, if it can be called so, that companies have is the fact that in a majority of the cases, the MD or the GM is responsible for the function. In this case, integration can be said to be considered at the conception of a business strategy. The risk, however, is the focus of these personnel, which is to satisfy the business needs of the company more often than not at the peril of its workforce. Seven local and one foreign company have other professionals (financial or administrative staff) responsible. The disadvantage here is that though this person could be knowledgeable in people management, they are generally not involved in the conception of business strategies to allow for innovative developments and strategic integration of HR strategies. There is therefore a clear gap between formulation of business strategies and that of HR strategies not allowing for the desired fit.

Horizontal integration of a company's HRM dimensions

A horizontal integration is accomplished by developing a coherent and a well-knit range of interconnected and mutually reinforcing HR policies and practices. This requires the use of the 'bundling' approach of HR management (Armstrong 2001). The nature of the industry, however, does not allow for long term planning making it difficult for companies to clearly outline their strategies. The nature of employment, mainly casuals and the outsourcing of jobs contributes to the instability of companies. A company can however have its policies with each project having unique requirement that will call for unique strategies. Site managers are not equipped with the requisite skills and knowledge in managing people adequately. This requires that the HR Manager defines the role of these personnel and they be equipped with the requisite skills so as to take up this responsibility. Achieving horizontal fit will require that the various HR strategies cohere and are mutually supporting. This will require a deliberate attempt to 'bundle' so the process is driven by the needs and characteristics of the business.

Recommendations

It is essential therefore in cases where the MD or GM is in charge of people management to get some form of education on the need for integration, its advantages and how to integrate these functions. Not much can be done about the size and capacity of these companies. Majority of companies, especially local, cannot afford to employ a full time HR Practitioner. They can therefore employ the services of HR Consulting Services to aid in policy development, strategy design and development and general HR activities. Provided with the right information and assistance, companies can adequately integrate their HR strategies with their overall business strategies. HR literature does not specify who should be in charge of a particular HR activity. Therefore, depending on the structure of the organization, roles assigned to personnel should promote horizontal integration of the HRM function within organizations. Personnel should be trained and made responsible for specific HR activities. It will take a huge awareness campaign by stakeholders to ensure that this need for adequate integration of the HR function into the business strategies of organizations is adhered to by construction companies within this industrial sector.

CONCLUSION

The need for adequate integration, both vertically and horizontally, is essential for every organization, more so construction companies considering the nature of the industry. Unfortunately, the entire HR function has been relegated to the background by construction companies in Ghana. The majority of large construction companies in

Ghana do not have HR Practitioners responsible for people management. This is a result of the size of the companies, their resource bases and the fact that they do not see the importance of adequate people management. Fortunately, an influx of international construction companies as well as the industry loosing its professionals to other industrial sectors have introduced competition for employees; requiring local companies and to some extent foreign companies to improve their working conditions and manage people better. Ensuring a vertical integration to ensure the HR strategy is in tune with the business strategies of the company and a horizontal integration of the various HR activities will therefore not only provide companies with the needed competitive advantage but also ensure workforce commitment and increased productivity and performance.

ACKNOWLEDGEMENTS

The authors would like to thank: Mr and Mrs O. B. Agbodjah; OBA Engineering Limited, Building and Civil Engineering Contractors; Vector Morrison (Ghana) Limited, Building and Civil Engineering Contractors; M.Barbisotti and Sons Limited, Building and Civil Engineering Contractors; Ablakwa Development Limited, Building and Civil Engineering Contractors; and Kwame Nkrumah University of Science and Technology.

REFERENCES

Anvuur, A and Kumaraswamy, M (2006) Taking Forward Public Procurement Reforms in Ghana. ***In****:* Construction in Developing Economies - New Issues and Challenges, *CIB W107 Construction in Developing Economies International Symposium*, 18 - 20 January. Santiago, Chile.

Armstrong, M (2001) *A Handbook of Human Resource Management Practice*. 8Ed. London: The Bath Press Ltd. CPI Group.

Baldacchino, G (2001) Human Resource Management Strategies for Small Territories: An alternative proposition. *International Journal of Educational Development* **21** 205-215.

Barbbie, E. (1995) *The Practice of Social Science Research*. 7Ed. Wadsworth Publishing Company.

Budhwar, P S and Sparrow, P R (2002) An integrative framework for understanding cross-national human resource management practices. *Human Resource Management Review* **12** 377-403.

Dansoh, A (2004) Strategic planning practices of construction firms in Ghana. *Construction Management and Economics* **23** 163-168.

Druker, J, White, G, Hegewish, A, and Mayne, L (1996) Between hard and soft HRM: human resource management in the construction industry. *Construction Management and Economics* **14** 405-416.

Easterby-Smith, M, Thorpe, R, and Lowe, A (1991) *Management Research: An Introduction*. London: SAGE Publications Ltd.

Eddy, W (1981) *Public organizational behaviour and developments*. MA: Winthrop Publishers.

Egan, J (1998) *Rethinking Construction: The Report of the Construction Task Force*. London: Department of the Environment, Transport and the Regions.

Hall, L (2004) *HRM Practices and Employee and Organizational Performance: a critique of the research and Guest's model*. Cheshire: Manchester Metropolitan University.

Huselid, M A, Jackson, S E, and Schuler, R S (1997) Technical and Strategic Human Resource Management effectiveness as determinants of firm performance. *Academy of Management Journal* **40** 171-188.

Johnson, G and Scholes, K (1993) *Exploring Corporate Strategy*. Hemel Hempstead: Prentice-Hall.

Kish, L (1965) *Survey Sampling*. New York: John Wiley and Sons Inc.

Langford, D, Hancock, M R, Fellows, R, and Gale, A W (1995) *Human Resource Management in Construction*. Longman Science and Technical.

Loosemore, M, Dainty, A R J, and Lingard, H (2003) *Human Resource Management in Construction Projects*. London: Spon Press.

Miles, D and Ward, J (1991) *Small-Scale Construction Enterprises in Ghana: Practices, Problems and Needs*. Loughborough: WEDC Library

Ministry of Water Resources Works and Housing (2004) *Guidelines for Building and Civil Engineering Companies*. Ghana: MWRWH.

Mintzberg, H (1987) Crafting Strategy. *Harvard Business Review* July/ August, 66-74.

Mlinga, R S and Wells, J (2002) Collaboration between formal and informal enterprises in the construction sector in Tanzania. *Habitat International* **26** 269-280.

Morley, M J (2004) Contemporary debates in European human resource management: Context and Content. *Human Resource Management Review* **14** 353-364.

Osei-Asante, K A. (2005) Quantity Surveying Practice across Africa: The Ghanaian Experience. African Association of Quantity Surveyors 3rd General Assembly.

Ministry of Finance (2006) *The National Budget*. Ghana: MoF.

Tyson, S (1997) Human Resource Strategy: a process for managing the contribution of HRM to organizational performance. *International Journal of Human Resource Management* **8**(3), 277-290.

Wells, J (2001) Construction and capital formation in less developed economies: unravelling the informal sector in an African city. *Construction Management and Economics* **19** 267-274.

Wells, J and Wall, D (2003) The expansion of employment opportunities in the building construction sector in the context of structural adjustment: some evidence from Kenya and Tanzania. *Habitat International* **27** 325-337.

Appendix 1: Minimum Labour and Equipment Holdings Construction Companies in Ghana

	Building Companies				Civil Eng. Companies			
	I	II	III	IV	I	II	III	IV
Personnel								
Architect	2	1			2	1		
Civil Engineer	2	2			2	2		
Quantity Surveyor	2	1			2	1		
Surveyor	2	2	1		2	1	1	
Accountant	1	1			1	1		
Purchasing Officer	2	1	1		2	1	1	
Book-Keeper	4	2	1	1	4	2	1	1
Works Superintendent	10	6	2		10	6	2	
General Works Foreman	8	5	2	1	8	5	2	1
Carpentry Foreman	8	5	2	1	8	5	2	1
Mason Foreman	8	5	2	1	8	5	2	1
Painter Foreman	8	5	1	1	8	5	1	1
Steel Bending Foreman	6	4	1	1	6	4	1	1
Equipment								
Dozer 140 HP	1				1			
Hammer, Piling I Ton	1				1			
Dumpy Levels	2	2	1		2			
Mixer Concrete – 10CYH	2				2	2	1	
Concrete Mixer – 0.5 HP	2	2	1	1	2	2	1	1
Pumps Water – 90,000 L/Hour	1	1	1		1	1	1	
Pumps Water – 450,000/L Hour	1	1			1	1		
Tanker Water Towed 1500L	1	1			1	1		
Theodolite	1	1	1		1	1	1	
Tractor Farm	1	1			1	1		
Truck Tipper – 5/m3 (Hiring-Class 3)	5	3	1		5	3	1	
Truck Flat Bed	3	2	1		3	2	1	
Truck Water Min 500L	1				1			
Truck Pick-Up (Hiring i.e. Class 4)	5	3	1	1	5	3	1	1
Dumper	1	1	1		1	1	1	
Bender Bar Cutter	5	3	1	1	5	3	1	1
Dragline/Pile Driving Lead	1				1			
Excavator	1	1			1	1		
Vibrator (Poker)	3	2	1		3	2	1	
Tower Crane/Hoist	1				1			
Scaffold	2	1			2	1		
Carpentry Machines	1	1			1	1		

Source: Ministry of Water Resources Works and Housing Guidelines

Appendix 2a: Regional Distribution of Large Construction Companies

Region	Number of Firms
Southern Belt	
Greater Accra	20
Central	8
Volta	6
Western	2
Middle Belt	
Ashanti	6
Brong Ahafo	-
Eastern	2
Northern Belt	
Northern	1
Upper East	1
Upper West	3
Total	49

Source: 2004 Membership Register, ABCCG

Appendix 2b: Operational Financial Ceiling for a 3 year period of Financial Sub Classification of Construction Companies

FINANCIAL CLASS	BUILDING AND CIVIL ENGINEERING COMPANIES
I	Over US$ 500,000.00
II	US$ 200,000.00 - 500,000.00
III	US$ 75,000.00 - 200,000.00
IV	Up to US$ 75,000.00

Source: Ministry of Water Resources, Works and Housing, Ghana (2004)

CONSTRUCTION IN SHANGHAI: ISSUES IN TECHNOLOGY TRANSFER

Sivaguru Ganesan[1] and John Kelsey[2]

[1]*CUPEM, University of Hong Kong, Hong Kong and DPU, University College London, London W1, UK*
[2]*Faculty of Built Environment, University College London, London W1, UK*

Successful assessment of technology transfer (TT) to developing countries should include a test as to whether such transfers have contributed significantly to providing higher quality inputs into the wider domestic industry, in terms of materials, equipment, labour and management. Higher quality inputs will require proportionately rising absorptive capacity locally to accommodate transfers of embodied and disembodied knowledge in numerous forms. Many developing countries fail in their efforts to modernize construction either on account of investment shortfalls, or simply due to not employing an optimal mix of domestic and imported resources when the investment climate is favourable. Shanghai stands out for its success in gradual modernization of construction using TT from overseas in China's post-1978 reform period. This paper examines, following questionnaire-based surveys and interviews, steps taken in Shanghai to promote TT. China has placed a balanced emphasis on upgrading building materials and equipment, design and construction, and built up an impressive absorptive capacity in urban locations, with modernization of the entire industry in prospect. China has used primarily domestic resources and initiatives, and transferred from overseas resources and skills that are in short supply or not yet developed locally. Yet the task of modernization is only in early stages. The paper draws useful lessons for developing countries from Shanghai's achievements so far in modernization.

Keywords: absorptive capacity, China, developing countries, foreign investment, technology transfer.

TECHNOLOGY TRANSFER AND ABSORPTIVE CAPACITY

Technology transfer in construction is concerned with conveying embodied and disembodied knowledge from one entity to another within a country, or from one country to another. Embodied knowledge is commonly transferred through building designs, equipment, materials and software. Disembodied knowledge is largely concentrated in human skills. The acquisition of more productive human capital in all relevant forms is the critical goal in transfer, absorption and adaptation of new technologies (Dunning 1993: 287; Ganesan and Kelsey 2006). Ultimately the output of construction depends on the quantity and quality of its inputs. Thus technology transfer deals with the entire range of construction inputs and components, not just in their production systems, but in the much fragmented processes leading to their assembly at specific sites. An assessment of technology transfer to developing countries should include a test as to whether such transfers have contributed significantly to providing higher quality inputs into the wider domestic industry, in

[1]sganesan@hkucc.hku.hk

terms of materials, equipment, labour, management or other inputs – whether locally manufactured or imported.

Higher quality inputs will require proportionately rising absorptive capacity locally to accommodate transfers of new embodied and disembodied knowledge in numerous forms (Abbot 1985; Akubue 2002). In a simplified form, absorptive capacity is seen as equivalent to effective demand for any good or services required. Matching incremental increases in effective demand should be the supply of higher quality construction inputs. The investigation of this supply–demand dynamic in a free enterprise economy needs to consider hard issues of incentives for and returns on investments required, as well as users’ ability to pay for construction goods and services. Affordability criteria for significant social construction in developing countries introduces additional burdens in technology transfer.

Because the industry produces a vast range of goods and services in a developing country, varying from the international sector producing luxurious offices, hotels, modern industrial complexes and infrastructure, to conventional or traditional semi-permanent houses and buildings, technology transfer studies must necessarily be based on a disaggregated structure of construction output.

Main features of and barriers to technology transfer

A disaggregated model as defined above facilitates identity of higher quality inputs required, as well as improvement in absorptive capacity needed to match planned improvements in quality and quality of output – say for a sub-sector such as conventional house building. For technology purposes, construction in developing countries can be broadly categorized as follows, and discussion in this paper will be limited to these (Turin 1978; Wells 1986):

- advanced international technologies – buildings and infrastructure;
- modern urban construction;
- conventional construction;
- traditional (largely rural, low income) shelter and buildings.

Further, deficiencies in absorptive capacity can be appreciated readily when we examine the following domains related to domestic construction:

- national policies to expand domestic capacity;
- design knowledge and skills;
- technologies in materials, equipment and energy supplies;
- procurement and collaboration practices;
- construction skills, organization and management.

Professionals and managers in developing countries are likely to promote internal diffusion of advanced technology into any of the above areas if the particular technology can demonstrate the following characteristics:

- increase capital and/or labour productivity and cut costs;
- increase quality of finished products within the user’s means to pay;
- maintain optimal resource balance appropriate for a developing country.

The first of these is a foremost challenge in any country, and is a principal motivation for adoption or adaptation of modern technologies in industrialized countries. The diffusion of advanced technologies into conventional and traditional construction is severely limited in developing countries by the inability of users to pay for them in the absence of public sector subsidies. Ambitious attempts to transfer technologies to conventional and/or traditional construction in particular have faltered on such grounds (Ganesan and Kelsey 2006; Akubue 2002; Simkoko 1992; Imbert 1990). On the other hand, transferring new technology into the modern construction sector is relatively better accomplished because the affluent clients of private construction are able to pay for them, or the national governments underwrite investments in modern public infrastructure projects such as highways, port and harbour or power supply projects where these new technologies are incorporated.

The third issue emerges as a major problem in developing countries with limited foreign exchange earnings or reserves at any time. In these countries, foreign earnings or foreign loans and grants are required for import of technologically advanced inputs, or to manufacture them locally. For internal transfer of technology to be sustainable over the medium to long term within a large recipient industry, like construction, a country in the earlier stages of development should use foreign resources in proportion to its foreign earnings. Advanced technology transfer and domestic capacity growth are not mutually exclusive provided considerations to maximize the productivity of available scarce resources enter the choice of technologies in their use (Streeten and Stewart 1973; Ganesan 1979: 40–1; Streeten 1995). Higher absorptive capacity requires increased expenditure to raise construction output. Many developing countries fail in their efforts to modernize construction either on account of investment shortfalls, or simply due to not employing an optimal mix of domestic and imported resources even when the investment climate is favourable. The 1997 Asian Crisis is a constant reminder of such dangers arsing from resource imbalances (Ganesan 2000: 30–81).

Within a broader understanding of issues affecting technology transfer outlined above, it is possible to evaluate success or failure in technology transfer empirically by examining the changes in inputs and output, considering either a single sub-sector in detail, or aggregate construction, where relevant input data cannot be disaggregated. This may be described as a preliminary, resource-based, input–output approach to evaluate technology transfer. This procedure will be used to study construction industry changes in Shanghai.

Technology transfer in Shanghai

Shanghai stands out for its success in modernization of construction using technology transfer from overseas in the People's Republic of China's post-1978 reform period. China has placed a balanced emphasis on upgrading building materials and equipment, design and construction, and built up an impressive absorptive capacity in urban locations, with modernization of the entire industry in prospect. A number of initiatives were implemented. These are examined below in terms of the five domains listed above, that support advances in domestic construction capabilities.

Policies to expand domestic capacity

The post-1978 reforms in PRC emphasized improvement in productive capacity of the economy and social conditions of the people. Modernization and technological upgrading using foreign resources was a strategic decision of the leadership. A favourable national economic climate fuelled the rapid expansion of absorptive capacity for technology transfer. In the 25-year period from 1978, as GDP went up 9.4 times, construction expanded 10.4 times. Construction's share in GDP rose from 3.8% in 1978 to 6.9% in 2003 (National Bureau of Statistics of China 2005, 3-1: 53–6). The public sector itself is a major investor in vital infrastructure provisions, aided by a rapid increase in state revenues in the recent period. Total government revenue in GDP increased from 11.2% in 1994 to 18.5% in 2003 (National Bureau of Statistics of China 2005, 8-1: 288). The public sector is also a major collaborator with foreign and other domestic parties.

As mentioned above, an appropriate balance in the use of domestic and foreign resources is essential to sustain technological upgrading over the longer term. The government essentially adopted two major strategies towards this end. First, it opened the economy to private domestic and foreign capital and embarked on an export-led development drive. This led to a huge build-up of foreign currency reserves through export of a vast array of goods and services – reported to be US$1 trillion in November 2006 (www.chinability.com accessed 5 March 2007). Second, as foreign investors started taking advantage of China's unlimited and cheap labour supply, including a large pool of relatively better skilled workers, the government gave incentives to foreign direct investment (FDI) as the favoured means to support higher growth and upgrade technologies notably in enterprises targeting the export market. The large domestic market was also a major attraction. From 1978 to 2005, China used US$637 billion in FDI (www.chinability.com accessed 5 March 2007; National Bureau of Statistics of China 2005). Both strategies supported one another. The PRC government set in motion a series of measures to transfer advanced technologies, such as the advanced technology provisions promulgated by the State Science Commission on 4 October 1979 (Wang 1998). FDI passes risk in investments to the investors themselves, and protects the sovereign hold on foreign reserves of the country, adding to overall currency stability. Technology transfers involving FDI usually provided simultaneous transfer of management know-how, personnel training, continuous cooperation between the local and foreign parties involved and better prospects of replication of the same technology in existing or newer enterprises (Zhang 1994).

Urban and infrastructure construction emerged as a key sector in these reforms. The 1978 reforms created a favourable economic climate for rapid build-up of the absorptive capacity for technology transfer in the construction sector. The goals of technology transfer that enhance, in essence, this absorptive capacity are periodically established in the PRC Five Year Plans. For example the Tenth Five-Year Plan (2001–05) emphasizes further improvements in construction capacity, and rising of the standards of design, construction and management to guarantee quality projects. (National Bureau of Statistics of China 2003). In pursuit of advanced technologies, China has been following the strategy of 'upgrading the domestic industry depending primarily on domestic resources and initiatives, and transfer from overseas of resources and skills that are in short supply or not yet developed locally' (Ganesan 2000: 301–2). A number of initiatives were rapidly implemented in Shanghai, Beijing and other urban locations.

Shanghai is the commercial capital of China. The population is currently around 18 million with a per capita income of US$6200, representing over a 20-fold increase since 1978. This has been made possible by a 9–10% annual growth in real GDP during the same period. Total GDP of Shanghai stood at US$109 billion in 2005, representing 5% of China's GDP. Expansion in construction activity was an integral part of this remarkable spurt in economic growth. No other city has built as much as

Shanghai in the last 25 years, and improved its built environment so much. New strategies maximized housing investments through the combined initiatives of the state, local authorities, private and public enterprises and individuals (Zhi 1993: 82). Housing contributed nearly a third of this construction expenditure. Nearly 100 million square metres of housing space were completed in the first two decades of reform, in search of a target of 10 square metres of living area per person.

The massive expansion in construction expenditure has facilitated advanced technology transfer. A rapidly increasing volume of construction at the same time allows a smooth adjustment of a mix of technologies so as to eliminate labour-reducing adverse social consequences. Shanghai attracted the most amounts of foreign investment, contracting for over US$100 billion of FDI till 2005. In 2005, Shanghai contracted FDI of US$13 billion, and actual realized investment was US$6.9 billion. (*People's Daily Online*, 6 December 2005). Construction secures its inputs from practically all other sub-sectors of the economy. Foreign investment in the overall economy helped construction. Specifically, construction and real estate, together with investment in building materials and services amounted to nearly 50% of total foreign investment in Shanghai up to 2000. Foreign investment and related services covered practically all the five domains of construction identified above as significant to technology transfer. The Shanghai Municipal Government periodically issued regulations that facilitated the setting up of foreign funded enterprises (FFEs). Significant among these is the notification titled 'The Measures of Shanghai Municipality on the Administration of the Use of Land by Foreign Invested Enterprises' (Ganesan 2000: 301–38; State Statistics Bureau of China 1997).

Design knowledge and skills

Design is the phase where most of the critical decisions on advancing the technological content of the construction product are taken. China already possessed design and construction skills that were the envy of many less developed nations. Collaboration with foreign firms had the goal of improving the absorptive capacity of local firms. The PRC government laid down rules to support this specific objective.

Foreign design firms have usually been required to cooperate with local design firms at the conceptual design stage – especially in high-tech projects. Detailed designs are normally undertaken by a local design firm. For example, in the landmark Jian Ma Building, a US firm – Skidmore Owings & Merrill – collaborated with the Shanghai Institute of Architectural Design and Research. The owner usually entered into separate contracts with the design parties involved. Similar collaborative arrangements were undertaken with leading international firms from Hong Kong, Japan, USA, Germany, etc. This collaboration enhanced the technological capability of the partnerships, and in the medium term enabled the local architects to absorb additional conceptual design and related skills. Among those skills transferred around 1990 were the following (Ganesan 2000: 318–19):

1. the use of enabling technologies such as computer-based design communications, using advanced design software;
2. the better integration into construction design of comparatively technologically advanced inputs such as:
   - structural steel components;
   - higher strength concrete;

- superior building finishes;
- high speed elevators;

3. the better organization and application of processes such as design coordination, change control and constructability reviews.

The East Asia Design Institute of Shanghai has demonstrated the benefits of such collaboration with its own design of the 456 metre Shanghai Oriental Pearl tower. The Shanghai Opera House (including its acoustics) was also designed solely by this Institute.

Technologies in materials, equipment and energy supplies

China's building material industry was sufficiently developed by the 1970s that buildings of up to 30 storeys were being erected out of locally produced material and components. Under the post-1978 reforms, China adopted dual strategies: First, direct imports were allowed. Second, from the 1980s China set up international joint ventures (IJVs), and particularly from 1992, allowed fully foreign funded enterprises (FFEs) as well, with FDI, to boost local production of building services, materials, fittings, components and finishes to high international standards.

The construction boom of the 1990s, for example, generated a huge demand for imported high quality products: bathroom fittings, escalators and elevators, communication equipment, air-conditioning equipment, marble, glass curtain walls, lightweight and high strength structural steel products, fire safety, security and environmental control equipment, hardware items, floor and wall panelling, etc.

However, a real boost in supply of construction resources came after the enactment of the Provisions of the State Council of the People's Republic of China for the Encouragement of Foreign Investment in China in 1986. Benefiting from the financial and other incentives, FDI in production enterprises grew rapidly. Incentives were granted to construction material, transportation, machinery, communications, metallurgy and other sectors that directly or indirectly supported construction.

Cheap labour and the huge domestic market as well as the potential to export a part of the products, led to a massive increase in manufacturing in these sectors. By the end of 2000, the State Bureau of Building Material Industry (SBBMI) had approved over 5000 new building material industries with overseas funding with a total contract value of over US$15 billion. These included cement, glass and glass products, aerated and structural concrete, steel products, high quality ceramic tiles, sanitary ware and stone products, decorative materials – practically all that were imported during the earlier period of the reforms. It is estimated that output from the FFEs now accounts for 20–30% of national output or sales in many products, such as plastic products, door and window frames, metal products, electrical machinery and tools, and furniture. Probably a quarter of all materials and components used in new construction in Shanghai are from IJVs – though nationally the percentage would be much smaller. In a selected set of the most advanced buildings in Shanghai, the IJV-produced proportion of all materials and components used is estimated to be in the range of 50–80% (Ganesan 2000: 320–5).

Prior to 1978, China had a large construction equipment manufacturing sector, supplying concrete mixers, bulldozers, tower cranes, road rollers, etc. These were also exported. However, a significant technological gap always existed between domestically produced and most internationally traded plant. This was first bridged after 1978 by imports of sophisticated machinery, and now IJVs are active in upgrading manufacturing technology in this sector (State Statistics Bureau of China 1997; Ganesan 2000).

Finally, the expansion of energy supply capacity is probably one of the most important constraints on the growth of both output and productivity in industrial activities in developing countries. In China, nearly a third of all energy used is taken up in (1) production and transport of materials; and (2) building construction and maintenance. Growth in energy supply at 6% per annum in the 1980s had been insufficient to match higher demand from construction (Ganesan 2000: 327–9); however, more recently, China's Primary Energy Production has accelerated from 31.84 quadrillion BTU to 44.10 quadrillion BTU in 2003 (www.eia.doe.gov/ accessed 10 May 2007).

Procurement and collaboration practices

The government gave encouragement to the construction sector to maximize the use of foreign resources including preferential long-term loans to form joint ventures (JVs) within foreign engineering, design, consulting and research institutes in order to enhance technological capability, and increase investments in construction in general. These initiatives enhanced domestic capacity in practically all fields, notably in improving local architectural design and construction skills, technological capability of construction enterprises, R&D for building and energy-saving technologies, bi-lateral and multi-lateral funding for the financing of environmental and urban infrastructure projects (Song 1998; Carrillo 1996). Foreign companies are required to set up their own offices, staff them adequately with technical and management personnel, before they are allocated any work, a condition that encourages integration into the local industry even if only on a temporary basis.

In 1988, there were nearly 1000 foreign construction enterprises (including those from Hong and Taiwan) licensed in China. Foreign companies can form joint ventures with local parties guided by the Law on Joint Venture with Chinese and Foreign Investment and other laws of the Ministry of Construction and other ministries. There were 425 JVs registered in 1998. The foreign contractors on their own or in JVs are allowed design and construction work in fully foreign funded projects or on special projects where there is no local expertise. Many foreign construction companies function as subcontractors – particularly those who are specialist contractors – providing specialist skills and expertise which domestic contractors do not possess. Subcontracting is widespread in China and is actively employed in all construction-related businesses including the JVs.

Construction skills, organization and management

TT efforts covered practically all areas of construction relevant to the achievement of the goals identified in the Five-Year Plans so as to provide a comprehensive framework. For example, the central, provincial and municipal governments have promulgated the Construction Law, the Contract Law and the Tendering Law to guide all related activities in the construction sector. The unified Construction Law was effective from 1 March 1998 (Lu and Fox 2001). It is apparent that many of these laws were influenced by overseas practices that were transferred to China after 1978.

China achieved an impressive volume of construction output in the pre-1978 years. This could not have been achieved without a good deal of organization, self-management and use of conventional management procedures. The then labour-intensive methods of construction were organized with a high ratio of managerial workers. New management skills were demanded for those post-1978 projects that attracted foreign capital flows, including FDI – notably in the areas of import of materials, implementation of new procurement systems, and collaboration with foreign parties. The Ministry of Construction set up advanced management training systems, and often foreign firms organized special programmes to train local workers engaged in JVs (Ganesan 2000: 327). Furthermore, in practice, local construction skills were steadily upgraded through institutional collaboration and subcontracting arrangements employed in the modern foreign funded projects, as described in the preceding section.

PROSPECTS FOR TT: DISCUSSION

The paper identifies the significant role of FDI in general and especially the critical contributions of overseas construction firms and personnel in construction in the technological upgrading in Shanghai and other urban locations in China. We cannot achieve technological upgrading if industrial output is stagnant. It is clear that resources for industrial expansion and technology transfer were mostly mobilized locally or through earnings from export-led economic expansion. Total exports grew from US$194.9 billion in 1999 to US$438.2 billion in 2003. Total imports increased from US$165.7 billion to US$412.8 billion in 2003 (National Bureau of Statistics of China 2005, 18-1: 713). It is noted that foreign investment constituted only 4.7% of total investment in fixed assets in 2003 nationally, indicating its limited but catalytic role (National Bureau of Statistics of China, 2005, 6-1: 187). This supports the theoretical position taken in this paper that a correct balance in the use of domestic and foreign resources is an essential condition for successful technology transfer to developing territories. China’s strategy closely followed this position as pointed out above.

The real tests of successful diffusion of advanced technologies though are whether new knowledge and skills have been permanently transferred to institutions and individuals within the recipient industry; whether such knowledge and skills are being applied to new projects; any technological gaps have been reduced especially design, construction and management deficiencies in the local firms; domestic capacity to reproduce embodied knowledge in materials, components and equipment has increased and finally, sources of funding projects including minimal supplies of foreign exchange are adequately established and moderately sustainable (Kumaraswamy 1994; Devapriya and Ganesan 2004; Ganesan and Kelsey 2006). The increasing number of complex projects being planned and executed within Shanghai, the minor share of foreign resources (less than 5%) in capital construction financing, and the build-up of large foreign currency reserves as evidenced in this paper indicate that internal diffusion of advanced technologies as defined is being achieved.

If transfer of technology can be viewed as a process of introducing higher quality inputs (materials, skills, equipment, etc.) into construction, the success observed in the more developed sub-sectors in Shanghai validates an input-based approach to implementing technology transfer. There was clearly a multi-faceted and integrated attempt to upgrade the quality of all inputs. Equally, the failure to significantly penetrate conventional and traditional construction may be explained by some critical inputs being not available to these sub-sectors in adequate quantities or within affordable prices.

Building materials and components constitute by value the largest input. Particularly impressive are the rapid advances in manufacturing of quality products through IJVs within the past 20–25 years. The example of China has highlighted three issues as being critical to technology transfer especially in manufacturing:

- selection of projects based on advanced technology;
- training of Chinese workers in advanced technology;
- training in management skills.

The joint ventures face problems of technological gap between the parties, underutilization of equipment, competition from cheaper and lower quality products, financial viability, and the ultimate challenge in earning net gains in foreign exchange. The primary objective with respect to technology transfer in the coming decade will vary according to the construction or building material supply sub-sector. Consider the materials sector. The recent expansion in industrial capacity throughout China is remarkable. For example, cement capacity rose from 2.3 million tons in 1999 to 12.7 million tons in 2003 (National Bureau of Statistics of China 2005: 214). The total industrial value added in all building materials in 2003 amounted to an impressive US$17.35 billion. Despite the technological advances in Shanghai, only about a quarter of all building materials supplied are produced to higher quality in the IJVs (Ganesan 2000: 337). The percentage of high quality materials produced on a national scale would be much smaller. Probably the greatest challenge is to modernize those building materials production units established before the 1978 reforms. From the 1960s, there were over 8000 factories set up and managed by the China (New) Building Materials Corporation, affiliated to the State Bureau of Building Materials Industry (SBBMI). These are largely state-owned enterprises (SOEs). Additionally, there are a large number of urban and rural collectives active in production. The materials sector produces over 500 products. Slow increases in factor productivity have led to stagnation (UNIDO 1992: 111). Critical problems in this sector are a product mix unsuitable for the current Chinese market and poor quality of products (Hannan 1995). The sector is known to suffer from archaic equipment, low labour productivity, financial instability, manufacturing delays, etc.

New FDI is planned, therefore, to be directed into these ‘traditional’ enterprises that provide basic inputs like materials and equipment manufacturing, manpower training, etc., in order to modernize them, and have the maximum multiplier effect in achieving the technology transfer goal. In this task, intra-national (domestic) technology transfer can play as important a role as foreign to domestic transfers. The Japanese government has long-established procedures for intranational technology transfer; for example, technologically developed firms operating nationally are required to form joint ventures with local firms when executing regional projects (Ganesan 1982: 153–82). However, restructuring of SOEs in China has not been always successful (Huchet and Richet 1998). Economic viability of restructuring is likely to be determined by the state of technology in current use, construction market conditions and competition from IJVs already set up. If restructured enterprises focus on products for the rural sector, their profit margins are like to be small or even negative. Further, since 1992, foreign investors have preferred to set up fully foreign funded enterprises (FFEs). This preference for FFEs will reduce foreign capital flows to SOEs further (Wang 1998). The pace of modernization of the existing building material sector is likely to influence technological upgrading of all four construction subdivisions especially the conventional and traditional building activities.

Khan (1999) has argued that FDI as a medium of technology transfer has been fairly successful especially in manufacturing. The same conclusion may be drawn with regard to modern urban and infrastructure construction. The FDI component constitutes only a fraction of the total national expenditure on construction. In order to promote technological advances on the scale required in all China, further mobilization of foreign and local resources, advanced manpower training and investment in R&D are necessary. The rate of growth of FDI in key industries and its catalytic role are critical. Limited foreign resources need to be guided into strategic enterprises with the maximum multiplier impact on technology transfer. Essentially this strikes a balance in productive capabilities and planned technological levels (Wang 1998). Cement, glass, natural stone, inorganic non-metal industries and building material manufacturing equipment are among the high-tech units identified by the State Administration of Building Materials industry for further upgrading. A socially responsible employment policy needs to complement technology transfer efforts. It is also noteworthy that little progress in technology transfer will be achieved nationally without improving energy supplies significantly.

Technology transfer is not a politically neutral activity (Ofori 2000). Mainland China’s (PRC) political system is unique. China provides a huge market for every construction sub-sector, and demonstrates unrivalled market power in negotiating technology transfer mechanisms with overseas parties. China’s record foreign earnings in the post-1978 period have provided a firm platform to engage in advanced technology transfer. Yet Chinese experiences are not irrelevant to construction expansion in DCs in general. There are bound to be procedures that can be adopted successfully in different countries regardless of their social systems – admittedly with different degrees of success (World Bank, 1984). One can recognize such common patterns of growth in the proliferation of science and technical knowledge across national boundaries. All things considered, China’s experience in technology transfer since 1978 validates an integrated approach to increasing the supply of higher quality inputs while maintaining a sustainable ratio of foreign to domestic resources. China also provides an outstanding example of the importance of developing a domestic absorptive capacity to integrate advanced technologies from overseas.

CONCLUSIONS

Because of data limitations, this paper has drawn conclusions mainly relevant to construction in Shanghai. In Shanghai, the international technologies sector (complex buildings and modern infrastructure) and modern urban construction have benefited noticeably from technology transfer in the post-1978 period. The 1978 reforms provided a favourable climate for new investment in urban growth and capital construction, with a defined role for FDI in diffusing advanced technologies. Within such a climate, policies adopted within the construction and building materials sectors have produced favourable results in terms of sustained increases in construction output while inputting higher quality resources. It is noted that conventional urban and traditional rural construction are still largely dominated by pre-1978 technologies. Chinese experience confirms that diffusion of advanced technologies is more manageable in the more developed construction sub-sectors servicing the more affluent urban areas.

ACKNOWLEDGEMENT

We are grateful to Professor Zheng Shilling, Professor Zhi Wenjun, Zhou Qing and others from Tongzhi University, who helped us to conduct surveys of design and construction firms in Shanghai.

REFERENCES

Abbot, P G (1985) *Technology transfer in the construction industry*. London: Economist Intelligence.

Akubue, A I (2002) Technology transfer: a third world perspective. *Journal of Technology Studies*, **XXVIII**(1), 14–21.

Carrillo, P (1996) Technology transfer joint venture projects in developing countries. *Construction Management and Economics*, **14**, 45–54.

Devapriya, K A K and Ganesan, S (2002) Technology transfers through international subcontracting in developing countries. *Building Research & Information*, **30**(3), 171–82.

Dunning, J H (1993) *Multinational enterprises and the global economy*. Wokingham: Addison-Wesley.

Ganesan, S (1979) Growth of housing and construction sectors: key to employment creation. *Progress in Planning*, **12**, 40–1.

Ganesan, S (1982) *Management of small construction firms*. Tokyo: Asian Productivity Organisation.

Ganesan, S (2000) *Employment, technology and construction development: with case studies in Asia and China*. Aldershot: Ashgate.

Ganesan, S and Kelsey, J M (2006) Technology transfer: international collaboration in Sri Lanka. *Construction Management and Economics*, **24**, 743–53.

Hannan, K (1995) *China, modernisation and the goal of prosperity*. Cambridge: Cambridge University Press.

Huchet, J F and Richet, X (1998) China in search of an efficient corporate governance system. Paper presented at the Conference on China Economic Reform: Comparative Perspectives, March 1998, Centre for Asian Studies, University of Hong Kong.

Imbert, D C (1990) Human issues affecting construction in developing countries. *Construction Management and Economics*, **18**, 219–28.

Khan, Z S (1999) Patterns of direct foreign investment in China. World Bank Discussion Papers, The World Bank, Washington DC.

Kumaraswamy, M M (1994) Evaluating and controlling effective technology transfer in the construction industry. Paper presented at the TT Conference, June, London.

Lu, Y J and Fox, P W (2001) *The construction industry in China: its image, employment prospects & requirements*. Geneva: International Labour Office.

Ofori, G (2000) Globalization and construction industry development: research opportunities. *Construction Management and Economics*, **18**, 257–62.

National Bureau of Statistics of China (2003) *China Statistical Yearbook 2002, the Tenth Five-Year Plan of the construction industry*. Beijing: China Statistics Press.

National Bureau of Statistics of China (2005) *China Statistical Yearbook 2004*. Beijing: China Statistical Press.

Simkoko, E E (1992) Managing international construction projects for competence development within domestic firms. *International Journal of Project Management*, **10**, 12–22.

Song, C H (1998) *Beijing Review*, 21–27 December, 17–18.

State Statistics Bureau of China (1997) Investment in building materials sector. *Beijing Review*, 11–17 March.

Streeten, P P (1995) *Thinking about development*. Cambridge: Cambridge University Press.

Streeten, P P and Stewart, F (1973) Conflict between output and employment objectives in developing countries. *In*: P Streeten (Ed.) *The frontiers of development studies*. Macmillan.

Turin, D A (1978) Construction and development. *Habitat International*, **3**(1/2), 33–45.

UNIDO (1992) *China: towards sustainable industrial growth*. Oxford: Blackwell.

Wang, L I (1998) Review and prospects of utilisation of FDI in Mainland China. Paper presented at the Conference on China Economic Reform: Comparative Perspectives March, 1998, Centre for Asian Studies, University of Hong Kong.

Wells, J (1986) *The construction industry in developing countries: alternative strategies for development*. London: Croom Helm.

World Bank (1984) *The construction industry: issues and strategies in developing countries*. Washington, DC: World Bank.

Zhang, Z Y (1994) Foreign direct investment and technology transfer: the cases of China and Vietnam. *In*: A T H Chin and H G Ng (Eds.) *Economic management and transition towards a market economy: an Asian perspective*. Singapore and London: World Scientific.

Zhi, W J (1993) Housing and its development in Shanghai. *In*: S Zheng (Ed.) *The research on human settlements in Shanghai*. Tongji University Press.

ARTISANAL MATERIALS FOR SUSTAINABLE CONSTRUCTION IN DEVELOPING COUNTRIES

O A K'Akumu,[1] A Blyth and B Jones

Property and Construction, University of Westminster, School of Architecture and the Built Environment (SABE), 35 Marylebone Road, London NW1 5LS, UK

Sustainable construction is a major challenge to developing countries more so when it comes to the use of artisanal materials in the construction process. This review identifies and examines the challenges facing developing countries in this respect: environmental degradation, poverty, informal settlements, inappropriate regulatory mechanism, inappropriate technology, and neglect in research and development debates. It notes that research and development at local level is necessary for addressing the challenges posed by the use of artisanal materials from sustainable development point of view. Above all, it recommends research into the area of artisanal materials and sustainable construction.

Keywords: building regulation, developing countries, intermediate technology, standardization, technology transfer.

INTRODUCTION

This paper intends to justify the need to undertake research on artisanal material production for purposes of mainstreaming sustainable development in the construction industry of developing countries. The paper defines artisanal materials as well as sustainable construction in a developing country context.

The paper poses questions about the challenges to sustainable construction in developing countries and whether artisanal materials can address these challenges. The aim is to spark debate and stimulate research undertakings in this grey area.

One of the pertinent challenges to sustainable construction in developing countries remains sheer lack of knowledge about it or what it may entail for developing countries. As noted by du Plessis (1999, 2007), the thinking in sustainable construction is dominated by issues to do with developed countries and that are in fact irrelevant to the developing country situation.

The paper is an exploratory work that seeks to persuade that research into the case of artisanal materials is a significant way of addressing the issue of sustainable construction in the developing countries. The paper is merely a review of the situation in order to propose a certain research agenda. For that matter, it does not apply any case study or empirical analysis.

[1] o.kakumu1@wmin.ac.uk

CONCEPTS AND DEFINITIONS

Artisanal materials

The term artisanal is an adjective of the word ‘artisan’ and simply refers to any thing associated with artisans. The English dictionary meaning of an artisan is of a person who applies manual skills to do work. See the following definitions for example:

- ‘Somebody who is skilled at a craft’, Bloomsbury (2005).
- ‘Skilled manual worker or craftsman’, Oxford (1993).
- ‘A worker who has special training in a manual skill’, Collin (2006).
- ‘A skilled workman; craftsman’, Collins (2005).
- ‘One who is employed in any of the industrial arts; a mechanic, handicrafts man, artificer’, Oxford (1971).

These definitions follow the traditional concept of an artisan as an industrial craftsman; who is skilled, trained and specialized in a particular trade. In the pre-industrial revolution era, artisans consisted of guilded workers who were trained through apprenticeship (Eisenberg 1991). In the construction sector, artisans included painters, plasterers, masons, roofers, joiners, carpenters, et cetera (Gould 1993). To date, such artisans still exist in the construction sector whether in developing or developed countries.

Gore (2004) considers the term craft as any human transformation of raw material into another object. This transformation, he notes, can happen:

- By hand.
- With the assistance of machine tools.
- Through the agency of automated manufacturing equipment.

Artisans are the category of workers who undertake this transformation largely by hand or to some extent with the assistance of machine tools.

Artisanal materials are, therefore those human rather than machine made materials used in the building of structural elements in the construction sector. Examples of artisanal materials may include: manually cut dimension stone, manually broken ballast, manually fetched sand, manually made bricks/blocks etc. Artisanal materials may be considered the antinomy of industrial materials as conceptualized in Terner and Turner (1972), i.e. hand crafted and individually made materials that imply:

- Lack of standardization of the final product (production skills and sites are varied, sporadic and may be irregular).
- Lack of concentration of production and marketing (small scale and sporadic/fragmented).
- Lack of mechanization or automation (labour intensive).

In these characteristics lie the challenges and opportunities for artisanal materials in the urban context where demand for construction products remains high due to urbanisation processes and the rate of use of materials is faster thereby favouring industrial production.

This concept of artisanal materials may but does not necessarily include traditional materials. The latter are construction materials that were used by local communities prior to foreign/colonial intervention. For example, in Kenya, makuti (palm fronds) roofing was used in the coastal areas while grass thatch was predominant in the hinterland. Non-traditional materials on the other hand are materials whose usages were introduced through colonial intervention even if some of them were locally available; these include cement, bricks, dimension stone, sawn timber, sand etc. the materials could have been locally available but the technology for exploiting them had not been introduced. Secondly, they may not have been fully integrated into the local construction tradition.

The dichotomy of industrial/artisanal materials is technology/process based while that of traditional/non-traditional is temporal based i.e. past and present or ancient or modern. On the whole, artisanal materials may be either traditional or non-traditional depending on whether they were used by the society in the past or whether they are recent additions from foreign cultures and practices.

Reasons why artisanal producers tend to thrive in developing countries include:

- Some natural resource materials do not exist in substantial quantities to warrant large-scale exploitation.
- The construction that takes place at localized levels is largely undertaken by individual (other than corporate) developers who rely on materials from non-corporate sources usually identified or attained through personal relations.
- It is easier for artisanal producers to reach developers even in remote areas.
- Construction industry in these countries is mainly a preserve of artisan labour force that is able to form linkage with artisanal sources of materials.
- Artisanal producers do not use heavy equipment and hence can move from place to place in search of material which they can accumulate into adequate quantities.
- Artisanal producers are more distributed and hence their impact on the environment is much less visible hence tolerable.
- Artisanal producers can viably supply even very small developers with low demand that is highly fragmented.

It is for the above reasons that artisanal producers dominate production and supply of materials like: sand, dimension stone, slab stone, bricks, and ballast. Sand for example is universally used as small aggregates in the composition of concrete in Kenya; however, the production and distribution of sand is entirely left to the work of artisans.

Sustainable construction

Sustainable construction is perceived as a concept that has been coined for the purpose of mainstreaming the principles and practice of sustainable development in the construction industry (Hill and Bowen 1997; Miyatake 1996). Construction is related to sustainable development to the extent that it affects the environment, economy and society; the three form the key aspects of sustainable development. In all cases, the effect of construction can either be positive or negative or both. In the sphere of environment, for example, Horvath (2004) sees construction as one of the largest users of energy, material resources and water, and also as a formidable polluter. These are negative aspects but the positive ones include the fact that construction improves the human living or working environment to habitable conditions.

Since sustainable construction is based on environmental, economic and social factors that differ globally, it may not be easy to define the term. But du Plessis (2002), who had the mandate to do so, have given a definition that is closer to the developing country situation. The authors define sustainable construction as ‘a holistic process aiming to restore and maintain harmony between the natural and the built environments and create settlements that affirm human dignity and encourage economic equity’ (du Plessis 2002: 8). This definition covers all the three aspects of sustainable development: environment (natural and built), economic and social. The social aspect may not be overtly explicit in the semantics but is well represented in the concepts of dignity and equity. Dignity implies sustainable construction has to ensure socially acceptable living environments while equity implies equitable use and distribution of resources generated or consumed in the process of construction. This definition also clearly captures the aspect of informal settlements, which is the main challenge for sustainable construction in developing countries.

Scholars conceptualize sustainable construction in a cradle to grave imagery. This life cycle approach can be divided into three distinct phases: production phase, use phase and decommissioning phase (Rohracher 2001; Rwelamila *et al*. 2000).

Developing countries

Crump (1991) defines developing countries simply as countries that do not have sophisticated industrial bases to their national economies; their economies are characterized by abundant, cheap, unskilled labour and scarcity of capital for investment. It is these two key factors – abundant labour and scarce capital – that lends these countries’ production set-ups to artisanal production; where production is confined to hand or tools operations as already pointed out under artisanal materials production.

Apart from the low industrial base, developing countries are said to have also a low human development index (HDI). Developing countries are classified under low HDI countries meaning they have low scores on longevity, knowledge and standards of living, a condition that implying a lot of work that has to be done in order to bring the index to the threshold standards (UNDP 2000).

The factors of HDI (longevity, knowledge and standard of living) are issues to do with sustainable development. Also, a great part of the work to be done in this case require establishment of infrastructure which therefore involve construction as a major activity in development endeavours. These contribute to the interconnectedness among low human development, sustainable development and hence sustainable construction as discussed further in this paper.

THE CHALLENGES TO DEVELOPING COUNTRIES

Developing countries face the following challenges concerning sustainable construction.

Rapid development

Developing countries, as the name implies, are in the initial process of economic development or industrialization. This situation entails a great demand on construction products hence high volume of construction activities. In developing countries infrastructure is lacking and has to be hurriedly put in place in order to support various activities for purposes of economic and social progress (Majdalani *et al*. 2006). Infrastructure involves a host of construction products such as buildings (industrial, residential, commercial, social, administrative), and civil engineering structures such as roads, bridges, dams and airports (Bourdeau 1999).

The high volume of construction activities brings certain implications for sustainability; these include the limited environmental resources fro undertaking construction projects and the potential damage to the ecological balance. Construction, for example, require materials that have to be obtained from the natural resource base e.g. cement production involves the mining of limestone. Construction also leads to damage of environmental resources such as loss of flora and fauna in the construction of roads or displacement of people in the construction of dams.

Another aspect of economic development that is common for developing countries involves urban development. Development has brought with it rapid urbanization that puts undue pressure on the supply of construction products. Urban development as part and parcel of economic development therefore builds up the demand for construction products.

Poverty situation

The greatest challenge to developing countries today is the abject poverty that most of their citizens languish in. For that matter, every industry, construction included, is challenged to function toward poverty reduction. Construction is better put in this case because it can provide employment to some of the poorest groups of peoples. It employs unskilled and semi-skilled labour given its labour intensive nature.

Construction materials, apart from the finishes, are largely unprocessed and semi-processed products mean that even the poor can benefit down the supply chain. Construction activity takes place at various scales ranging between small and large. This means that even small-scale operators can participate in the industry, therefore giving opportunity for the poor to make contributions and earn a living.

One other advantage construction has is that it uses materials from within the local area. This enables it to generate a lot of economic opportunities at the grassroots level thereby benefiting local development. Because of these advantages construction is generally seen as a significant industry in the Keynesian economic model that developing countries have adhered to for so long. It is known to have significant multiplier effect in the economy in general. For that matter it can be instrumental in developing sustainable livelihoods for people at local level. This is a novel challenge that has not been explored but that can be of great benefit. Can we integrate construction industry with local livelihood strategies?

Informal settlements

One of the main characteristics of urban development in developing countries is informal settlements. In Kenya, for example, it is estimated that over 60% of the urban dwellers live in squalid conditions in informal settlements (in the form of slums and squatter settlements). Unfortunately, the problems of informal settlements are mainly seen as social problems, i.e. problems of housing, social equity, welfare, or distribution of income and wealth (especially land). The problem is rarely seen as a problem of the construction industry. This proposition reiterates that as much as the problem of informal settlements belongs to the socio-economic realm with its impacts on the physical environment, it is a problem whose immediate causes lie in the structural inefficiencies of the construction industry. Hence its immediate solution lies with restructuring of the industry by recognizing and promoting sustainable construction practices.

Regulatory mechanism
According to van Bueren and Priemus (2002), institutional factors could form the greatest barrier to the attainment of sustainable construction. One of the greatest challenges of sustainable construction in developing countries is the institution of regulatory mechanism. Majdalani *et al*. (2006: 34) observe that ‘inadequate construction standards and lack of sound urban regulations (or enforcement of existing regulations)’ aggravate environmental degradation. In developing countries, the mechanisms may not be there, or if they are there, there may not be political will to enforce them, or they may have been inherited from the colonial past without any aspirations from the local society whom sustainable construction are supposed to benefit.

Lessons from the developed world
The other challenge of sustainable construction is whether these countries can learn from the sustainable construction experiences of the developed countries. The latter countries have faced their own challenges in the development process. The question is, can the developing countries learn from the others’ mistakes and successes so that they do not fall prey to the same development path. According to du Plessis (2007), the level of underdevelopment in developing countries provides them an opportunity to avoid the problems experienced in the developed countries. The question therefore is: are developing countries in a position to learn from the developed world?

Inappropriate technology
Technology involves a serious challenge for sustainable construction in developing countries. Ofori (1998) noted that the diffusion of modern ways of building and the use of materials without consideration of local, environmental and cultural is a practice inimical to the attainment of sustainable construction. The challenge for developing countries is therefore to identify and develop appropriate technological practices to ensure sustainable construction.

Neglect in international debate
Another challenge sustainable construction is facing in the developing countries is lack of recognition in the international arena where issues to do with sustainable construction are being debated, formulated and prioritized for implementation. Du Plessis (1999) decried the developing countries have been excluded in the sustainable construction debates whereas more than two-thirds of the world population live in these environments. But it behoves these countries to have their own specific agenda to present at the debate. Perhaps they have not been included so far because not have not demonstrated any need to be included in the debate.

THE CASE OF ARTISANAL MATERIALS

The challenges of sustainable have particular implications for the use of artisanal materials in developing countries. Does the use of artisanal materials in the construction industry exacerbate or ameliorate the developing country situation?

Damage to the environment

We have noted that construction does a lot of damage to the environment. According to Horvath (2004) opposition to large-scale construction projects is growing world over. This could be because their environmental damage is enormous and obvious. However, many small-scale works, especially those catering to the residential needs of the population, can easily escape the attention of environmentalists. Unfortunately, this is the segment of the industry where artisanal producers operate.

Artisanal exploitation of natural resources in other sectors like mining and fishing have been shown to cause serious environmental damage; see for example Mensah and Antwi (2002), Campredon and Cuq (2001), Hawkins and Roberts (2004), Rutterberg (2001), in the case of fishing; and MMSD (2003), ILO (1999), Quironga (2002) and Ogola *et al*. (2002), in the case of mining. In the construction sector, artisanal exploitation of natural resources for construction purposes may be damaging to the environment but has not been given adequate consideration. Examples here may include alluvial sand mining, stone quarrying, clay brick making, green timber exploitation etc.

Poverty reduction

Artisanal production of materials is a potential means by which the construction sector can contribute to poverty reduction through sustainable livelihood strategies. As in the case of mining, artisanal production has the potential for employment creation since it can be a means of survival for large numbers of workers and their families (Zamora 2000). But economic impact goes beyond the support of workers and their families to include support for whole local economies by creating demand for goods and services (MMSD 2003).

Informal settlements

Informal settlements are where the poor in urban areas live. They are the same people who also provide labour and skills in the use of artisanal materials where construction is concerned. If artisanal materials are well understood and improved through formalization and value addition, they can provide cheaper resources for self-help and low-cost housing. For example, if techniques of production is improved and accessibility and use are encouraged, materials like green timber from traditional forests, soil blocks etc., can be of acceptable use while stone and sand may be cheaper through elimination of inefficiencies.

Regulatory mechanism

Currently, the regulatory mechanism for construction materials in developing countries does not support the artisanal industry. For most of the countries with a colonial past the use of the materials are outlawed through building standards. This means locking out a good chunk of resources from the local economy and consigning it to the informal or black market economy thereby making it difficult for the artisans to earn their living. The regulations force the artisans to pay protection fees to the local governmental agents. Regulations like bans also make it difficult for individual artisans to operate in the exploitation of materials like sand. Cartel networks of middlemen then come in to control the market and buy at low prices from the artisanal producers. These agents only help to make the operations of artisanal producers inefficient in economic terms. On the other hand if these operations were to be formalized and included in the mainstream economy the efficiency in the use of artisanal materials would be increased.

Lessons from the developed world
The development process in the developed world included the industrialization of the construction process. Although industrialization of the construction process and materials has made it possible to produce building at shorter intervals and en masse to meet the rising demand, the transformation of buildings from a craft to manufacturing industry has also come with some unwanted consequences such as loss of aesthetics or threats to health such as sick building syndrome. In countries like the UK today, an obvious longing for the craftsmen's handiwork is seen in the new buildings constructed within elegant facades of the glorious past. The greatest lesson for developing countries is that industrialization, on which they are so keen, is not always the best options where the building industry is concerned. The developing countries could as well build and maintain their own craftsmanship through artisanal materials.

Inappropriate technology
Artisanal materials are what are available locally for building construction. In most cases they require traditional technology. Suppressing the use of artisanal materials therefore means promoting foreign knowledge and technology that may not be appropriate for local conditions. This results into a drain of local resources to foreigners and also makes it difficult for local people to help themselves with local resources hence making them poorer. This is not a sustainable construction industry. In clay brick making, for example, Parry (1979: 3) noted that 'the very high mechanized and automated plants rely on electric power and the high grades of fossil fuels such as natural gas and propane while traditional plants may use scrub wood or even camel dung as their source of process energy (other than human muscle-power)'.

Neglect in international debate
As far as sustainable construction is concerned, the developing countries could as well contribute the issue of artisanal materials. Production of materials by artisans is a rampant phenomenon in the construction industry with serious sustainability implications in developing countries. This requires further research and debate for purposes of development in the industry.

WAY FORWARD

The paper has looked at the challenges sustainable construction as a principle and a practice pose for the developing world. As a principle, it has certain limitations; for example, little is known about it from the developing country perspective. The reason that has been advanced is that developing countries are ignored in the international fora (du Plessis 1999, 2007). But the international community is not guilty of this neglect; because neglect begins at home where scholars and policy makers have not bothered with certain obvious aspects like the use of artisanal materials. The paper therefore recommends that researchers should probe further into the phenomenon of use of artisanal materials in construction at local levels to inform policymakers and contribute to the knowledge of sustainable construction up to the global level.

Research into artisanal materials from sustainable construction perspectives will be able to resolve the pertinent issues to do with environmental damage, sustainable livelihoods, inadequate housing, inappropriate regulatory mechanisms and appropriate technology that currently beset the construction sector in the developing countries.

The first author, for example, is conducting doctoral studies on the economic use of artisanal building materials in Nairobi.

REFERENCES

Bloomsbury Concise English Dictionary (2005) 2ed. London: A&C Black.

Bourdeau, L (1999) Sustainable development and the future of construction: a comparison of visions from various countries. *Building Research and Information*, **27**(6), 354–68.

Campredon, P and Cuq, F (2001) Artisanal fishing and coastal conservation in West Africa. *Journal of Coastal Conservation*, **7**, 91–100.

Collin, P H (2006) *Dictionary of Business*. 4ed. London: A&C Black.

Collins English Dictionary (2005) 7ed. Glasgow: HarperCollins Publishers.

Crump, A (1991) Dictionary of Environment and Development: People, Places, Ideas and Organizations. London: Earthscan.

Du Plessis, C (1999) Sustainable development demands dialogue between developed and developing worlds. *Building Research & Information*, **27**(6), 378–89.

Du Plessis, C (2002) Agenda 21 for Sustainable Construction in Developing Countries CSIR, CIB & UNEP-IETC, Pretoria - CSIR Report BOU/E0204.

Du Plessis, C (2007) A strategic framework for sustainable construction in developing countries. *Construction Management and Economics*, **25**(1), 67–76.

Eisenberg, C (1991), Artisans' socialisation at work: Workshop life in early nineteenth-century England and Germany. *Journal of Social History*, **24**(3), 507–20.

Gore, N (2004) Craft and innovation: serious play and the direct experience of the real. *Journal of Architectural Education*, 39–44.

Gould, R V (1993) Trade cohesion, class unity, and urban insurrection: Artisanal activism in the Paris Commune. *American Journal of Sociology*, **98**(4), 721–54.

Hawkins, J P and Roberts, C M (2004) Effects of artisanal fishing on Caribbean coral reefs. *Conservation Biology*, **18**(1), 215–26.

Hill, R C and Bowen, P A (1997). Sustainable construction: principles and a framework for attainment. *Construction Management and Economics*, **15**(3), 223–39.

Horvath, A (2004) Construction materials and the environment. *Annual Review of Environment and Resources*, 181–204.

ILO (1999) Social and Labour Issues in Small-scale Mines. Report for Discussion at the Tripartite Meeting on Social and Labour Issues in Small-scale Mines, Geneva, 17–22 May, ILO, Geneva.

Majdalani, Z, Ajam, A and Mezher, T (2006) Sustainability in the construction industry: a Lebanese case study. *Construction Innovation*, **6**, 33–46.

Mensah, J V and Antwi, B K (2002) The problems of artisanal marine fishermen in Ghana: the way ahead. *Singapore Journal of Tropical Geography*, **23**(2), 217–235.

Mining Minerals and Sustainable Development (MMSD) (2003) *Breaking New Ground*. London: Mining Mineral and Sustainable Development Group, International Institute for Sustainable Development and Earthscan Publications.

Miyatake, Y (1996) Technology development and sustainable construction. *Journal of Management Engineering*, July/August, 23–7.

Ofori, G (1998) Sustainable construction: principles and a framework for attainment—comment. *Construction Management and Economics*, **16**, 141–5.

Ogola, J S, Mitullah, W V and Omulo, M A (2002) Impact of gold mining on the environment and human health: A case study of Migori gold belt, Kenya. *Environmental Geochemistry and Health*, **24**, 141–58.

Oxford Dictionary for the Business World (1993) Oxford: Oxford University Press.

Oxford English Dictionary, The Compact Edition, Volume I (1971) Oxford: Oxford University Press.

Parry, J P M (1979) *Brick making in Developing Countries*. Watford: BRE.

Quironga, E R (2002) The case of artisanal mining in Bolivia: Local participatory development and mining investment opportunities. *Natural Resources Forum*, **26**, 127–39.

Rohracher, H (2001) Managing the technological transition to sustainable construction of buildings: a socio-technical perspective. *Technology Analysis & Strategic Management*, 13(1), 137–50.

Rutternberg, B I (2001) Effects of artisanal fishing on marine communities in the Galápagos Island. *Conservation Biology*, **15**(6), 1691–9.

Rwelamila, P D, Talukhaba, A A and, Ngowi, A B (2000) Project procurement systems in the attainment of sustainable construction. *Sustainable Development*, **8**, 39–50.

Terner, I D and Turner, J F C (1972) *Industrialized Housing: The Opportunity and the Problem in Developing Countries*. Washington DC: USAID.

UNDP (2000) Human Development Report 2000. New York: United Nations Development Programme.

Van Bueren, E M and Priemus, H (2002) Institutional barriers to sustainable construction. *Environment and Planning B: Planning and Design*, **29**, 75–86.

Zamora, A (2000) International Initiatives on Small-scale Mining: Lessons from Columbian coal experience. *Minerals and Energy*, **15**(1), 31–5.

AN ECONOMIC & SOCIAL PERFORMANCE FRAMEWORK FOR ENGINEERING AND CONSTRUCTION FIRMS OPERATING IN DEVELOPING COUNTRIES

Matthew Lynch[1] **and Petter Matthews**

Engineers Against Poverty, 3 Birdcage Walk, Westminster, London, SW1H 9JJ, UK

While most corporate engagement with global poverty centres on philanthropy, the opportunities for firms to contribute to poverty reduction through their core business activities are significantly greater. This particularly applies to the engineering and construction sector due to the significant interface of its value chain with local economic and social development and the fundamental societal importance of creating and maintaining infrastructure. There is broad scope for firms within this sector to identify mutual beneficial action to advance business strategy and contribute to local development and poverty reduction. Drawing upon Porter and Kramer's model for strategic corporate social responsibility (CSR), the Economic and Social Performance Framework (ESPF) has been developed for engineering firms to identify these mutually beneficial or 'shared value' opportunities. The ESPF has been applied to the operations of a large engineering services joint venture in the oil and gas industry in Timor Leste, and it was found to be a useful tool in identifying shared value opportunities to support the joint venture's business objectives.

Keywords: poverty reduction, developing countries, corporate social responsibility, corporate strategy, competitiveness.

INTRODUCTION

There are a growing number of corporations with an interest in poverty and sustainable development in developing countries. Organizations such as the Global Compact, World Business Council for Sustainable Development and Business Action for Africa demonstrate the scale of this interest within the corporate sector. Outside these multi-member platforms, individual firms typically engage with poverty through philanthropic activities. This may be in the form of donations to charitable organizations, support for staff volunteering or running small community service programmes around their developing country operations. The impact of these activities will always be limited relative to the size of the problem.

It is widely accepted that the private sector has a crucial role to play in poverty reduction through generating economic growth (Department for International Development 2006). However, firms can make important positive contributions to poverty reduction and the Millennium Development Goals (MDGs) not just through their role in generating growth,

[1] m.lynch@engineersagainstpoverty.org

but also by the way that they conduct their core business operations (World Bank Institute 2006). It is increasingly recognized that positive impacts on poverty through core business alignment rather than philanthropic approaches are more substantial, scaleable and sustainable (World Business Council for Sustainable Development 2005). These impacts include greater levels of direct and indirect local employment, advancement of productive skills, a more competitive local enterprise sector, local infrastructure development and more effective local institutions.

In a developing country context there is a strong mutual interest in development between the corporate sector and the host society. These societies need the positive social and economic benefits provided by private sector activity. Firms gain from a productive and stable society in a multitude of ways including access to a capable workforce, reliable supply chains, supporting infrastructure and the presence of good governance and the rule of law. This mutual dependence and common interest in development allows opportunities to create ‘shared value’, i.e. outcomes that benefit both business and society (Porter and Kramer 2006).

This opportunity for shared value is particularly strong in the engineering and construction sector. The activities of the sector are of fundamental societal importance, i.e. the creation and maintenance of essential social and economic infrastructure. Improved infrastructure helps reduce poverty directly by improving the access of poor people to services such as clean water and sanitation, health and education and by protecting them against humanitarian disasters. It also contributes indirectly through enhancing economic growth, raising agricultural productivity, reducing transport costs and generating income and employment (Jahan and McCleery 2005). In addition, engineering and construction activities by their nature tend to have a large physical, social and economic ‘footprint’. The scale of this multi-dimensional footprint provides a significant interface with a broad scope for mutually beneficial activities.

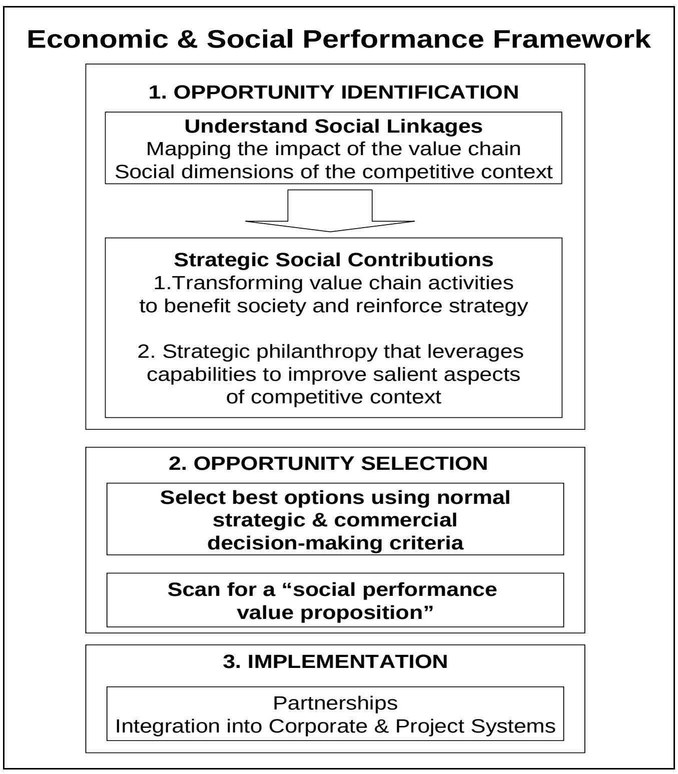
The size of this opportunity is magnified when the broader range of engineering activities outside public infrastructure is also considered. The extractive industries (oil, gas and mining), which are the actual or potential major source of economic wealth for many countries in Sub-Saharan Africa and Asia, require the involvement of engineering services in planning, design, construction, operation and maintenance. The extent of this involvement can be substantial; engineering, procurement and construction (EPC) contractors may be responsible for managing up to ninety percent of the value of potential employment and procurement opportunities in the construction phase of such projects (Overseas Development Institute 2005).

Recent forecasts indicate that by 2015 up to 80% of expenditure on new infrastructure will be in developing countries (Henry 2004). In the energy sector alone, almost half of total energy investment over the three decades to 2030 will take place in developing countries where production and demand are expected to increase most; this equates to approximately US$8 trillion or US$270 billion a year in investment (International Energy Agency 2004). Even in Africa, an area that has historically experienced chronic under-investment is seeing increased expenditure, facilitated in part by the creation of the Infrastructure Consortium for Africa (Department for International Development 2006). This expansion has been informed by the Report of the Commission for Africa (2005), which recommended that to meet the MDGs the region requires additional expenditure on infrastructure of US$10 billion a year up to 2010 with a further increase to $US20 billion a year for the following five years.

The size of the future market for engineering services, the opportunities for mutual benefits, and the urgency of the problem of poverty reduction create a strong imperative for developing a systematic approach for enhancing shared value. Engineers Against Poverty (EAP), in partnership with the Overseas Development Institute Business and Development Performance Programme (ODI), initially developed the Economic and Social Performance Framework (ESPF) as a contribution to this task, focusing on the opportunities presented by large engineering contractors in the oil and gas industry. It is presented in this paper by EAP as a general method, drawing substantially upon a model for strategic CSR developed by Porter and Kramer (2006). It is intended to be applicable for engineering contractors and consultants operating in a broad range of sectors and geographical contexts. The ESPF has been successfully used in practice in Timor-Leste (see Case Study below) and the authors are currently seeking additional opportunities for field application.

ECONOMIC & SOCIAL PERFORMANCE FRAMEWORK

The ESPF analysis is conducted in a similar manner to a strategic planning or risk assessment exercise, using a multi-disciplinary senior management team with knowledge of local operations and competitive context. It may be beneficial to also involve external expertise from the local context (e.g. local academia or social development consultants). The analysis should be conducted as early as possible in the project life cycle or involvement in a particular country or region. Paulson (1976) highlighted how decisions made in the earliest stages of projects have a relatively higher impact and lower cost. It follows from this that when socially beneficial strategies are integrated early in the design process, they are more likely to influence project outcomes and less likely to incur cost premiums. Figure 1 presents an overview of the method.



PF method overview

Opportunity identification

The first step in the ESPF is to identify the range of possible opportunities to make positive contributions to local social and economic development while contributing to business strategy. In the initial instance, this requires an understanding of the two major categories of interaction between a firm and its host society (Porter and Kramer 2006):

- *Value Chain Linkages* – almost every activity in a firm's supply chain touches on communities in which the firm operates, creating either positive or negative social consequences.
- *Competitive Context Linkages* – every firm operates within a competitive context, which significantly affects its ability to carry out its strategy especially in the longer term. Social conditions form a key part of this context particularly in developing countries.

Through the substantial array of likely linkages, the analysis then seeks opportunities to (ibid.):

- Transform value-chain activities to benefit society while reinforcing the firm's corporate strategy.
- Make strategic external contributions to improve salient areas of the firm's competitive context.

Two summary tables have been developed to facilitate this analysis, drawing on previous field research into the social aspects of engineering in developing countries (EAP and ODI 2003, 2004a, 2004b). Table 1 examines typical value chain linkages through project design and delivery, as well as the key supporting functions of procurement, human resources management and financial management. Table 2 examines the four interrelated elements of competitive context from Porter's "diamond" model of competitiveness (Porter 1990), and the social dimensions of each that are typically relevant to engineering activities. These tables are not comprehensive and there are also likely to be location and sector-specific opportunities; however, they can be used as a model to guide the analysis of the ESPF team.

Competitive context generally attracts less attention than value chain impacts; however competitive context can have far greater strategic importance for both companies and societies (Porter and Kramer 2006). One advantage for engineering firms in seeking shared value opportunities through the competitive context is that it reduces the constraints of aligning contributions with client requirements on individual contracts. There is also an increasing recognition of the significant role engineering and construction firms can play in contributing to the broader capacities of developing societies. The United Nations Millennium Project Task Force on Science Technology and Innovation explored this role in the context of the MDGs. The Task Force identified the importance of 'technological learning', a process of building individual and societal level capacities to apply knowledge and innovation to further economic and social improvement. The Task Force noted that (2005: 2): "Infrastructure development provides a foundation for technological learning, because it involves the use of a wide range of technologies and complex institutional arrangements. Policymakers need to recognize the dynamic role infrastructure development can play in economic growth and take the initiative in acquiring the knowledge available through international and indigenous construction and engineering firms".

Table 1: Shared value opportunities in the engineering and construction value chain

Business-Society Interactions in the Value Chain (derived from Porter and Kramer 2006)		**Example Shared Value Opportunities**	**Societal Benefits**	**Business Benefits**
Project Design & Delivery	• Integration of client (or national/local) poverty reduction objectives into design	• Alignment of design and delivery of project with the needs of local poor communities	• Meeting basic needs of local communities	• Reduced risk (reputation, social). • Greater user/customer acceptance
	• Project environmental, social & community impacts	• Comprehensive environmental and social impact analysis (ESIA)	• Minimize negative impacts on local communities	• Reduced risk (regulatory, reputation, social)
	• Utilization of labour-based technologies and construction methods	• Suitable works for application of labour-based methods include: general earthworks; road construction and maintenance; low level bridges; small dams and irrigation structures; water and sewerage reticulation; storm water drainage systems; low voltage electrical reticulation & electrification; and materials manufacture • Even with large complex projects, there are opportunities to use labour-based construction methods for sub-elements of work or ancillary infrastructure	• Additional income and skills for local people. • Evidence from a broad range of developing countries has shown that labour-based approaches created between three and five times as much employment and achieve cost savings of between 10–30% over equipment intensive methods of construction (ILO 2003)	• Reduced costs • Supporting 'social license to operate'
	Stakeholder engagement	• Primary stakeholders (especially local poor communities) fully engaged in design process	• Increased likelihood of community needs being met • Reduced risk of adverse impacts on communities	• Reduced risk (regulatory, reputation, social) • Greater user/customer acceptance
Key Support Functions				
Procurement	• Supply of materials, goods and services • Subcontracting	• Local supply of materials, goods and services. • Use of local subcontractors	• Additional income to local economy • Small suppliers and subcontractors tend use more labour-intensive methods project increasing employment generation	• Access to suitable suppliers • Most efficient and effective supply chain • Advantages over competitors • Supporting 'social licence to operate'
Finance Management	• Financial transactions	• Increased use of local financial institutions for project fund transfers, disbursements etc.	• Assists in building the capacity of local financial institutions	• Reliable local financial services provider
Human Resource Management	• Recruitment polices • Training	• Preferential recruitment of local workers • Formal and on-the-job training programmes	• Additional income and skills for local people • Builds local skill base • Increased incomes for trainees	• Access to skilled local workforce • Advantages over competitors • Supporting "social licence to operate"
	• Health & safety management programmes	• Systems to prevent accidents and injuries in both the directly-employed and subcontractor workforce	• Reduced accident and injuries (and consequent risk of lost income and livelihoods for workers and their families)	• Reduced risk (regulatory, reputation, social)

Table 2: Shared value opportunities in the competitive context

Typical Elements of the Competitive Context (Porter 1990)		Example Shared Value Opportunities	Societal Benefits	Business Benefits
Factor (Input) Conditions Presence of quality specialized inputs available to firms	• Availability of capable local labour	• Support local vocational training initiatives	• Builds skill base of the local economy • Increased incomes for trainees.	• Access to skilled local workforce
	• Efficient physical infrastructure	• Align project or temporary (e.g. site access roads) infrastructure with local economic and social development priorities	• Provision of essential services • Additional economic growth	• Enhanced relationship with government and regulatory bodies
	• Administrative capacity of local government	• Provide technical assistance to third-party programmes (e.g. bilateral and multilateral aid organizations) working to develop local government administrative capacity	• More effective governance • Contribution to “technological learning”	• Enhanced relationship with government, regulatory bodies and third-party organizations
Context for Firm Strategy & Rivalry The rules and incentives that govern competition	• Transparency in procurement for engineering services	• Support for local industry-led or multi-stakeholder anti-corruption initiatives	• Corruption disproportionately affects the poor, potentially increasing the cost of services and siphons off resources that should be spent on communities (DFID 2006)	• Increased likelihood fn non-corrupt businesses winning contracts
	• Government and institutional capacity to identify, procure and manage infrastructure projects	• Provide technical assistance to third-party programmes to develop local government management and technical expertise	• More effective governance • Increased chance of successful delivery of infrastructure projects • Contribution to “technological learning”	• Enhanced relationship with government, regulatory bodies and third-party organizations
Local Demand Conditions The nature and sophistication of local customer needs	• Suitability of infrastructure for local needs.	• Design or pricing measures that provide access to affordable services for all people • Additional works to provide universal access to infrastructure services	• Provision of essential services • Additional economic growth	• Greater user/customer acceptance • Reduced risk (regulatory, reputation, social)
Related and Supporting Industries The local availability of supporting industries	• Availability of local suppliers.	• Support local enterprise development initiatives	• Additional income to local economy • Small suppliers and subcontractors tend use more labour-intensive methods project increasing employment impacts	• Access to suitable suppliers • Most efficient and effective supply chain • Advantage over competitors
	• Presence of industry clusters.	• Support the development of local complementary firms (e.g. survey, CAD/CAM, testing services)	• Additional income to local economy • Technological learning	• Access to suitable suppliers • Most efficient and effective supply chain • Advantage over competitors

Opportunity selection

The second stage of the ESPF process is to select those shared value opportunities that are the most valuable and ideally meet the normal selection criteria applied in the firm's commercial and strategic decision making. This will generally require a quantitative assessment of the costs and benefits. It is noted that many of the potential benefits may be difficult to quantify, requiring subjective judgements by the team conducting the ESPF analysis. Where the benefits are uncertain in terms of their likelihood or impact it may be appropriate to use an expected value approach, essentially considering the opportunities as "positive" project or business risks (Institution of Civil Engineers & Actuarial Profession 2005).

Transforming value chain activities may be attractive as alignment of activities with contract delivery can potentially make the additional cost and management effort minimal; however, the scope may be limited by the specifications or constraints of the client. The assessment of contributions to the firm's competitive context will depend on the firm's strategic time horizon, as these types of initiatives by their nature tend to be longer term. One feature of the engineering and construction sector is the periods between projects or contracts where a firm's resources are not fully utilized. This spare capacity could be used, for example, 'strategically' to support capacity building or training initiatives, simultaneously building the skill base of staff and further developing local knowledge and commercial relationships.

While the case for pursuing individual opportunities may be compelling, there may be also a broader opportunity to establish a social performance dimension to the firm's value proposition, i.e. the set of needs that a firm can deliver for its chosen customers that other cannot. As Porter and Kramer observe: "the number of industries and companies whose competitive advantage can involve social value propositions is growing" (2006: 91). Two examples of potential social value propositions for engineering firms operating in developing countries are explored below.

Superior local value chain

The difficulties of operating successfully in many developing economies particularly for many firms are exacerbated by access to an appropriately skilled workforce and quality suppliers. Building the skill base of local workers and suppliers and establishing productive linkages with these groups can be facilitated by both project-related value chain initiatives or through competitive context contributions. Over time, these linkages can create competitive advantage through both cost and efficiency gains, and advantageous positioning to deliver 'local content'. Many public and private sector clients specify various forms of local content requirement on the delivery of engineering projects and services (Hawkins *et al*. 2006). Oil and gas operators often need to meet challenging local content requirements as part of their agreements with governments and include these requirements in their tendering processes. This provides opportunities for engineering service providers in this industry to differentiate themselves from their competitors based on the strength and capacity of their local value chain.

Integrated social risk management

Projects in developing countries often encounter higher levels of 'social' risk, which arises through the interactions between a project and its local stakeholders. This elevated risk exposure is due to a range of factors including weak local governance, regulatory planning processes which may not fully take into account the views of local stakeholders, and the possible presence of latent or open conflict in the project vicinity. For the engineering industry, this situation is complicated by the increased risk aversion of many clients leading to the adoption of project models and contracting arrangements that transfer more risk to the contractor (Skeggs 2004).

It is increasingly acknowledged that to adequately address social risk, projects need to obtain a 'social license to operate', i.e. the informed consent and support of local stakeholders to construct and operate a project in their area. The well-documented potential risks of not seeking and developing this local support (e.g. protests, site blockades, attacks on property and staff, damage to reputation, reduced operational revenues through lack of user acceptance) can have significant negative financial implications for clients and financiers as well as their engineering consultants and contractors. Maximizing positive local benefits from projects is considered a key component of building a social license to operate. For many projects, aspects within the sphere of influence of engineering consultants and contractors are central to providing the benefits that many communities most value, such as designing for and delivering employment and local business opportunities. When benefits are aligned and delivered as part of the project, they can potentially constitute a cost-effective strategy for building better relationships with communities and managing risk. Engineering firms with specialist competencies in identifying, analysing and managing social risks can not only reduce their own risk exposures but also can offer this as part of an integrated risk management service to clients (EAP & ODI 2004a).

Implementation

The final stage of the ESPF analysis is to ensure that there are appropriate internal mechanisms for the implementation, management and monitoring of the selected shared value opportunities. In the initial instance, this may require modification or addition to core business and project management systems. An example could be a scenario where a firm identifies an opportunity to build a business development strategy based on its capabilities in developing subcontractors within its supply chain. It may be appropriate to make modifications to internal report structures to automatically capture quantitative data about the development of subcontractors (e.g. value of business on contracts, increase in total value of local contractors' business over time). This quantitative data can then be used to strengthen subsequent tender submissions, as well as enhancing the quality of a firm's CSR reporting. This type of integration will reduce or eliminate the additional management time required for administration. When value chain practices and contributions in competitive context are fully integrated, they may be difficult to distinguish from the day-to-day business of the firm (Porter and Kramer 2006).

It is important to note that engineering firms will not necessarily have 'in house' the full range of skills and resources to implement some of shared value opportunities arising from their operations. Multi-sector partnership models, such as that developed by the World Bank's Business Partners for Development Programme (www.bpdweb.com) may provide a suitable mechanism for that enables firms to work with 'non-traditional' partners and to tap into their competencies to meet business and development challenges in a way that adds value for each partner (Matthews 2005). Many governments and development agencies as well as NGOs are seeking opportunities to work with private sector firms as the importance of the private sector in poverty alleviation is increasingly recognized. Such partnerships can also ensure positive benefits are more sustainable and extend beyond the life of an individual contract. A useful starting point for the engineering and construction industry is the substantial body of knowledge developed within the industry in ‘internal’ project partnering i.e. relatively complex partnership arrangements between clients, contractors and subcontractors as a strategy for project delivery (Verschoyle and Warner 2001). Many of the key competencies for the developing and managing these relationships could be applicable in an external context.

TIMOR-LESTE CASE STUDY

This case study presents an analysis of the operations of a large engineering joint venture offering operations and maintenance services to the oil and gas industry in Timor-Leste. The information was initially presented in a report published by EAP and ODI (2007). It demonstrates an engineering firm developing a strong social performance dimension to their value proposition and winning business based on this value proposition. It shows how even specialized engineering services can generate shared value opportunities in supporting activities and contributions to the competitive context. It also provides an overview of the use of the ESPF tool in systematically identifying and analysing shared value opportunities.

The Clough AMEC Joint Venture (CAJV) is a partnership between two major engineering firms: AMEC plc and Clough Limited. In 2004, the CAJV bid for the first operations and maintenance services contract for the offshore assets of ConocoPhillips’ Bayu Undan Project, the first major oil and gas development in the Timor Sea. The contract requires provision of both offshore and onshore maintenance services ranging from minor fabrication work to major offshore shutdowns. The contract period is three years with the option of a two-year extension and with an approximate value of US$40M over the first three years.

The core value proposition of the CAJV is to provide proven high-quality engineering and maintenance services at a competitive price through efficient utilization of a unique global network of suppliers, subcontractors and skilled labour resources. Building on experience on the Shell Malampaya Project in the Philippines (EAP and ODI 2004b), the CAJV also added a social performance dimension to their value proposition i.e. integrating innovative strategies into contract delivery to help overcome barriers to Timor-Leste participation in the oil and gas sector. This social value proposition was informed by the following key strategic and commercial drivers:

- The Timor-Leste Government is seeking to maximize the local employment and commercial content through both the oil companies and their major contractors, and these aspirations are included in the Production Sharing Agreements with the oil companies. However, the lack of local capacity and the presence of established oil and gas support bases in Perth and Darwin in Australia represent strong inhibitors for the growth of a domestic support industry in Timor-Leste.
- ConocoPhillips is seeking to satisfy the aspirations of the Timor-Leste Government (within the commercial, technical and safety requirements of the project), in order to maximize their opportunities to secure additional exploration and production acreage.

As part of its bid offer, the CAJV included two innovative local content proposals aligned with the delivery of the technical requirements of the contract: a national employee resourcing strategy and the development of a common user support base

(CUSB) in Timor-Leste. The resourcing strategy was a rigorous, staged process of building the necessary competencies of successive groups of Timorese trainees to allow them to safely perform skilled trade work on the offshore facilities. The CUSB proposal entailed the construction and operation of a facility to attract suppliers and subcontractors to base themselves in Timor-Leste to provide a range of key support services including fabrication and machining, warehouse storage, lifting and freight services. It was proposed that the CUSB would be developed using a multi-sector partnership model between the private sector, the government and local development agencies, aiming to establish a sustainable long-term business with potential for growth beyond the current needs of the Bayu-Undan project and facilitating significant local skills and technology transfer. The CUSB proposal was accompanied by a detailed business plan.

The CAJV's social value proposition appears to have been highly successful in generating competitive advantage. According to statements made by the local regulatory authority and the client, these innovative proposals were material factors in the CAJV securing the contract. This is an important outcome as it provides direct evidence of the potential strategic and commercial value for engineering firms in establishing a social value proposition, particularly where this is aligned with the strategic priorities of the client.

At the mid-point of the Bayu-Undan contract period, an EAP/ODI research team visited Timor-Leste at the invitation of the CAJV. This visit was to facilitate the use of the ESPF method to scan for further opportunities to support local economic and social development. An earlier version of the ESPF was utilized in this exercise, which has some industry specific elements (e.g. an industry-specific opportunity list); however, the fundamental method is very similar to the version presented in this paper. Working with CAJV project staff, two additional shared value opportunities were identified to make strategic contributions to the local competitive context:

- Expansion of the national employee resourcing strategy to support the phased development of a local skills training capacity rather than relying on foreign training organizations.
- Support for the establishment of a dedicated enterprise development program for local businesses to support the development of their capacity to contribute to the oil and gas industry.

These initiatives would use the leverage created by the CAJV being the only major engineering services firm with operations in Timor-Leste to further consolidate their local competitive position. While the viability of these initiatives needs to be further assessed, the long term strategic focus of the CAJV and the relatively long contract period makes these contributions strategically attractive. In addition, the scanning of the local context identified numerous organizations with potential to provide the resources necessary to support the identified opportunities. Key potential partners include the World Bank, Asian Development Bank, USAID, the German financial development organization GMZ, CARE Timor-Leste and the Dili Institute of Technology. Initial discussions with these organizations indicated a strong willingness to consider partnership or collaboration initiatives. The CAJV was advised to consider positioning itself within a training or enterprise development collaboration as the provider of intermittent specialist and technical support, rather assuming the overall management responsibility and associated risks.

The ESPF was found to be a useful tool for identifying additional measures for the CAJV to contribute to Timor-Leste's development while advancing their own business strategy and competitive positioning. These additional contributions could be invaluable for increasing the capacity of the local economy to benefit from the oil and gas sector and would complement the establishment of the CUSB facility. In a broader sense, the Bayu Undan contract and the activities of the CAJV presents one of the single most important opportunities in Timor-Leste for the 'technological learning' process needed to increase the technical and managerial capacities within the local economy.

CONCLUSION

The ESPF is a systematic method for helping engineering firms to identify shared value initiatives that advance their business strategy and contribute to local social and economic development when operating in developing countries. It draws on a model for strategic CSR developed by Porter and Kramer as well as previous field research into the local social and economic development opportunities associated with engineering activities. The ESPF has been found to be a valuable tool for helping a firm refine its social value proposition and integrate it into its core business activities, as demonstrated by its application by an engineering joint venture in the oil and gas industry in Timor-Leste. The method will now be further tested to increase confidence in its general applicability.

REFERENCES

The Institution of Civil Engineers & the Actuarial Profession (2005) *Risk Analysis and Management for Projects*. London: Thomas Telford.

Commission for Africa (2005) *Our Common Interest – Report of the Commission for Africa*. London: Commission for Africa.

Department for International Development (DFID) (2006) *Eliminating World Poverty – Making Governance Work for the Poor – White Paper on International Development.* London: DFID.

Hawkins, J, Herd, C and Wells, J (2006) *Modifying infrastructure procurement to enhance social development*. London: Institution of Civil Engineers & Engineers Against Poverty.

Engineers Against Poverty (EAP) & Overseas Development Institute (ODI) (2003) *Enhancing Social Performance of the Engineering Services Sector Through Multi-Sector Partnering – Learning from Lot 3 of the Java-Bali 500kV Transmission Line Construction Project, Indonesia*. London: EAP & ODI.

EAP & ODI (2004a) *Enhancing Social Performance in the Engineering Services Sector through the Process of Risk (and Opportunities) Analysis*. London: EAP & ODI.

EAP & ODI (2004b) *Learning from AMEC's Oil and Gas Support Operations in the Asia Pacific Region: with case study of the Shell Malampaya Gas-to-Power Project.* London: EAP & ODI.

EAP & ODI (2007) *Learning from AMEC's Oil and Gas Support Operations in the Asia Pacific Region, Report II: with case-study of the Bayu-Undan Gas Recycle Project, Timor-Leste*. London: EAP & ODI.

Henry, W P (2004) Engineering Beyond Technology. Inaugural American Society of Civil Engineers (ASCE) Address, Baltimore, MD, October.

International Alert & EAP (2006) *Conflict Sensitive Business Practice: Engineering Contractors and their Clients*. London: International Alert.

International Finance Corporation (IFC) (2003) *Addressing the Social Dimensions of Private Sector Proje*cts *(Good Practice Note Number 3)*. Washington, DC: IFC.

International Energy Agency (IEA) (2004) *30 Key Trends in the IEA & Worldwide*. Paris: International Energy Agency.

International Labour Organisation (ILO) (2003) *Thematic Evaluation Report: Employment Intensive Investment and Poverty Alleviation*. Geneva: Committee on Technical Cooperation, ILO.

Jahan, S and McCleery, R (2005) *Making Infrastructure Work for the Poor: Synthesis Report of Four Country Studies Bangladesh, Senegal, Thailand and Zambia*. New York: United Nations Development Programme.

Matthews, P (2005) Briefing: Multi-sector partnerships for poverty reduction. *Engineering Sustainability 158 Issue ES1*. London: Institution of Civil Engineers.

ODI (2005) *Levers & Pulleys: Extractive Industries & Local Economic Development – Incentivising Innovation by Lead Contractors through Contract Tendering*. London: ODI.

Paulson, B (1976) Designing to Reduce Construction Costs. *Journal of the Construction Division*, ASCE, **102**(CO4), Proc. Paper 12600, December, 587–92.

Porter, M E (1990) *The Competitive Advantage of Nations*. New York: Simon & Schuster.

Porter, M E & Kramer, M R (2006) Strategy and Society: The Link Between Competitive Advantage and Corporate Social Responsibility. *Harvard Business Review,* **December**, 78–92.

Skeggs, C (2004) *Project Partnering in the International Construction Industry*. Geneva: International Federation of Consulting Engineers (FIDIC).

United Nations Millennium Project Task Force on Science Technology and Innovation (2005) *Innovation: applying knowledge in development*. Sterling Virginia: Earthscan.

Verschoyle, D and Warner, M (2001) *Learning from Project Partnering in the Construction Industry (Working Paper No.12)*. London: Business Partners for Development.

World Bank Institute (2006) *Business and the Millennium Development Goals: The Business Challenge Africa*. Background Paper to the 11th International Business Forum, 8–10 October, Bonn.

World Business Council for Sustainable Development (WBCSD) (2005) *Business for Development: Business Solutions in Support of the Millennium Development Goals*. Geneva: WBCSD.

SINGAPORE CONTRACTORS AND CONSULTANTS' PROJECT MANAGEMENT PRACTICES IN CHINA

Florence Yean Yng Ling[1], Sui Pheng Low[1], Temitope K. Egbelakin[1] and Shou-Qing Wang[2]

[1]*National University of Singapore, 4 Architecture Drive, Singapore 117566*
[2]*Department of Construction Management, Tsinghua University, Beijing, China*

China's construction industry presents many opportunities to foreign architectural, engineering and construction (AEC) firms. This paper reviews the general management practices adopted by foreign firms and investigates specific project management practices adopted by them on construction sites in China. Data were collected using a structured questionnaire from Singaporean AEC firms that had undertaken projects in China. A wide range of management practices are adopted by foreign firms in China. The most effective market entry modes are entering China as wholly owned foreign enterprises and forming project joint ventures with Chinese firms. The key business strategies include understanding clients' requirements, and offering superior products and services. At the construction site level, many project management practices focus on improving quality and communication. Unfortunately, risk management is not adequately implemented. It is recommended that foreign firms adopt some of the significant management practices uncovered in this study so that their projects in China may achieve better performance.

Keywords: China, international business, international project, internationalization, project performance.

INTRODUCTION

The growth in China's construction industry has created many opportunities for foreign architectural, engineering and construction (AEC) firms. However, undertaking construction beyond a firm's domestic market (home country) is generally more difficult to manage due to multiple ownerships, elaborate financial provisions, different political ideologies, uncertainties and complex risks that are unique to international transactions (Gunhan and Arditi 2005a). Contracting overseas construction projects such as in China is a high risk business, mostly because of the lack of adequate environmental information and local construction experience (Han and Diekmann 2001).

The objective of this paper is to investigate project management practices adopted by foreign AEC firms when undertaking projects in China. The findings would help identify management practices that could help foreign firms achieve project success in China. This study is important because many foreign firms venturing into China's construction industry for the first time would need to know key management practices that they should adopt to enhance project performance.

---

[1] bdglyy@nus.edu.sg

GENERAL MANAGEMENT PRACTICES IN CHINA

Gunhan and Arditi (2005b) developed the International Expansion Decision Model to help companies assess if they are ready for international expansion. Ling *et al*. (2005a) investigated entry and business strategies used by foreign AEC firms in China. They found that market entry modes used by foreign firms that lead to project success in China are: (1) setting up wholly owned foreign enterprises; and (2) forming project joint ventures (JVs) with local Chinese firms. Chan *et al*. (1999) also found JVs between Chinese and foreign firms would help bring about project success.

Jin and Ling (2005) developed models for predicting project performance in China using relationship-based factors. Critical relationship-based factors affecting project performance are: sufficient communication; absence of excessive interference by partners; adherence to mutual goals; and empowering staff with authority (Jin and Ling 2006). It can be interpreted that foreign firms should build cooperative and harmonious relationships with Chinese partners so as to achieve project success in China. Luo's (2001) study assessed management and performance of Sino-foreign construction joint ventures. He found that expatriates' high wages are heavy burdens to Chinese partners in Sino-foreign joint ventures. Gale and Luo (2004) investigated factors leading to success in the formation stage of Sino-foreign joint ventures.

Ling *et al*. (2005a) found that for foreign firms to survive in China, they must first bid low to win projects and then demonstrate high capabilities in project delivery by building to specifications and achieving high quality outputs. Ling *et al.* (2005b) identified enablers that would help foreign AEC firms win construction contracts in China. The study found that to win projects in China, foreign AEC firms need to: have good understanding of the Chinese market; provide project financing services; price competitively; and provide superior products or services. The study demonstrated that expertise in a specialized submarket and in a technical discipline can help firms win projects.

Ling *et al*. (2006) identified business factors that contribute to the success of projects undertaken by foreign firms in China. The most significant factor that contributes to project success is the firm's ability to understand clients' requirements. Other significant factors include: offering superior product and service quality; having superior capability; and having an excellent track record. Chan *et al.* (1999) also found that better understanding of national and local regulations, good relationships with local authorities and training of staff would help projects achieve success in China.

Ling (2005) identified benefits that foreign firms derive when undertaking projects in China. They include: diversification of business location; sales growth and expansion; higher profitability; enhanced core competency; acquisition of new capability; and formation of relationships with JV partners and clients from home countries. These benefits explain why there is a continual growth in the number of foreign AEC firms entering China.

PROJECT MANAGEMENT PRACTICES IN CHINA

The many factors that contribute to project success may be grouped into five main categories: project management actions; project-related factors; project procedures; human-related factors; and external environment (Chan *et al*. 2004). The objective of this study is focused on project management practices adopted by foreign AEC firms in China. This study adopted the PMI's nine project management knowledge areas and correspondingly, identified project management actions following PMBOK (PMI 2004). The project management functions or knowledge areas are: project scope, time, cost, risk, quality, human resources, communications and procurement management. The overall integration of these eight functions and the managing of externalities is the ninth project management function.

A review of literature revealed that many studies on project management practices affecting project success have been done. These primarily focused on indigenous firms working in their home countries (e.g. Konchar and Sanvido 1998; Chua *et al*. 1999; Ling 2004; Fortune and White 2006). For example, Ling (2004) investigated how the characteristics of projects, clients, consultants and contractors affect project performance when AEC firms are undertaking projects in their home countries.

Chen and Partington (2004) suggested that project management is not universal but culture-sensitive. It is essential to take account of the implications of cultural differences for people's conceptions of theories and project management practices when transferring them across cultures. Chan and Chan (2002) found salient differences in China's construction industry when compared to international modes of practice. For foreign AEC firms to thrive in China, there is a need to adopt project management practices that are suited for its construction industry.

Dai *et al*. (2006) did a case study of the Three Gorges Dam project in China, but this is not generalizable because it was based on one project. The project management practices adopted by foreign firms on construction sites (project level) remain unclear. This study therefore aimed to fill the gap by exploring the specific project management practices that Singaporean AEC firms adopt in China.

RESEARCH METHOD

This paper reports a part of the findings of a recently completed National University of Singapore funded research project undertaken to determine the international project management practices of foreign firms when handling projects in China. Seventy-eight specific project management practices were operationalized from PMI's (2004) nine knowledge areas, and their level of usage in China was tested in the fieldwork.

The research design was based on a survey, and data were collected through the post and via email. The data collection instrument was a questionnaire specially designed for this study. Respondents were requested to base their responses on one particular project that they or their firms had completed in China. Respondents were asked to indicate the project management practices adopted on a seven-point Likert scale and also their demographic and company characteristics. The questionnaire was pre-tested in a pilot survey before an industry-wide survey was conducted.

The population frame comprised Singaporean AEC firms that had undertaken and completed construction projects in China. The list of targeted respondents (N = 200) was drawn up from the records maintained by the Building and Construction Authority, professional institutions and other published information.

Data were analysed using SPSS software. This paper reports the t-test results. The mean of each variable was compared by conducting an independent sample t-test. A test value of 4 was used to test whether the means were significantly different from a mid-point of 4 on a Likert rating scale of 1 to 7. A project management practice is considered significant when $p< 0.05$.

CHARACTERISTICS OF THE SAMPLE

From the 200 questionnaires sent out, 33 responses were received (17% response rate). Details of the respondents and their projects are given in Table 1: 55% of respondents are contractors, 75% of bidding methods were either selective or negotiated.

Table 1: Characteristics of respondents and their projects

Characteristic	No.	%	Characteristic	No.	%
Designation			*Service provided*		
Upper management	8	24	Design and consultancy	5	15
Middle management	17	52	Management	10	30
Professionals	8	24	Construction	18	55
Experience in industry			*Ownership of project*		
≤ 3 years	8	24	Public sector	4	12
4–10 years	4	12	Public–private joint venture	4	12
11–15 years	4	12	Privately owned	24	75
16–20 years	12	36	*Gross floor area (m^2)*		
21–25 years	3	9	1000–10 000	6	22
> 25 years	2	6	10 001–50 000	4	15
Size of workforce			50001–100 000	3	11
10–100	9	31	100 001–150 000	7	26
101–500	9	31	150 001–200 000	5	18
501–1000	3	10	> 200 000	2	7
1001–3000	7	24	*Bidding method*		
More than 3000	1	3	Open	8	25
Annual revenue (USD)			Selective/prequalification	14	44
< $1M	1	6	Negotiation	10	31
$1M–$10M	7	41	*Facility type*		
$11M–$100M	4	24	General building	24	73
$101M–$200M	4	24	Manufacturing	9	27
> $200M	1	6	*Location of project*		
% of revenue from overseas			Shanghai	12	36
10%–20%	9	41	Suzhou	6	18
21%–30%	7	32	Beijing	4	12
31%–40%	3	14	Tianjin	3	9
41%–50%	0	0	Shenzen	2	6
> 50%	3	14	Chengdu	2	6
Contract sum (USD)			Kunming	2	6
< $1M	2	7	Wuxi	1	3
$1M–$10M	7	24	Fuzhou	1	3
$11M–$50M	7	24			
$51M–$100M	5	17			
$101M–$300M	8	28			

The majority of the respondents were middle management. The respondents had worked between three and 30 years (mean = 16 years) in the construction industry. Thirty of the 33 respondents were personally involved in the reported projects.

The respondents' firms engaged between 10 and 6000 employees, with an average of 975 employees. Results show that 62% of the respondents' firms had 500 or fewer employees. Annual revenue averaged US$70M. More than half of the firms had 30% or less of their revenue derived from overseas projects.

Respondents were allowed to report any projects that they had managed and completed in China. The majority of the projects reported by them were concentrated in the eastern region of China. Project sizes ranged from 2000 m^2 to 1 000 000 m^2 (mean = 128 330 m^2). The average contract sum was US$71.7M.

PROJECT MANAGEMENT PRACTICES ADOPTED IN CHINA

Seventy-eight project management practices were investigated, and 38 of them were found to be significantly adopted by Singaporean firms in China (see Table 2). These are now discussed.

Table 2: Significant project management practices adopted in China

Code	PM practices	Mean	t- value	p- value
	Scope management practices			
Scop14	Minimize claims or disputes in the contract	3.36	–2.11	0.04
Scop16	Manage the job as a whole integrated contract	4.24	–3.41	0.00
	Time management practices			
Time21	Early acceptance and approval of the schedule	4.58	2.09	0.04
Time24	Provide adequate equipment to deliver the service	5.39	6.55	0.00
Time25	Respond quickly to changes ordered by clients	4.79	2.74	0.01
Time26	Have one person overall in charge of the project schedule	2.61	–4.28	0.00
	Cost management practices			
Cost31	Have high quality cost data in China	4.70	3.17	0.00
Cost32	Have high quality financial management	4.58	2.38	0.02
Cost33	Have high quality planning in determining the resources required and quantities needed	4.64	2.44	0.02
Cost34	Have good cost control of resources	4.52	2.12	0.04
Cost35	Have a good system to monitor activities to detect cost overruns	4.52	2.23	0.03
Cost36	Have regular cost reporting and very close monitoring by HQ to control cost	4.94	3.60	0.00
Cost37	Have strong financial strength	5.64	8.05	0.00
	Quality management practices			
Qlty41	Have high quality control and quality management plans	4.88	4.23	0.00
Qlty42	Have good health and safety management in the workplace	4.64	2.16	0.04
Qlty43	Engage high quality managerial staff	4.94	4.41	0.00
Qlty44	Engage high quality professionals	4.79	3.44	0.00
Qlty46	Work with clients who demand quality output	5.97	10.82	0.00
Qlty47	Ensure high conformance to the requirements in the contract	5.48	7.42	0.00
Qlty48	Conduct regular reviews to ensure that output conformed to the requirements in the contract	4.70	2.81	0.01
Qlty49	Pay attention to environmental impact, sustainability and protection in the delivery of service	4.58	2.20	0.03
	Risk management practices			
	No significant practice found			
	Human resource management practices			
HRM61	Provide adequate staffing level to deliver the service	5.15	3.28	0.00
HRM64	Engage more Chinese nationals as technical staff/worker	5.30	4.89	0.00
HRM65	Provide extensive skills training for the Chinese workforce	4.76	2.75	0.01
	Communication management practices			
Com71	Have more face-to-face communication	5.03	3.92	0.00
Com72	Work with clients whom you have a good prior working relationship with	5.06	4.18	0.00
Com73	Work with project team members whom you have a good prior working relationship with	5.09	4.88	0.00
Com74	Work with people by whom you are likely to be engaged in future projects	5.15	3.98	0.00
Com75	Have frequent timely communication	4.97	3.64	0.00
Com76	Have high quality communication among team members, in terms of communications planning (information needs)	4.73	2.51	0.02

Code	PM practices	Mean	t- value	p- value
Com77	Have high quality communication in terms of appropriate generation, collection, dissemination, storage and disposition of project information	4.61	2.32	0.03
Com78	Work with project team members who share the same working language and could understand each other easily	4.88	3.02	0.00
Com79	Have well-managed public image and public relations	4.76	3.35	0.00
	Procurement management practices			
Proc85	Collaborate with foreign partners who are experienced and have high technical capability	4.48	1.94	0.06
Proc86	Select partners through negotiation instead of open bidding	4.64	2.03	0.05
	Integration management practices			
Integ91	Engage staff who are flexible and adaptable to China's political, economic and social landscape	5.21	4.47	0.00
Integ93	Communicate prioritized objectives to staff	4.79	3.12	0.00
Integ95	Minimize the use of political backing and outside influence in managing projects	2.91	–3.60	0.00

Scope management practices

Inadequate management of project scope affects contract duration, cost and quality negatively (Ibbs *et al*. 1998). Table 2 shows two significant scope management practices adopted by Singaporean firms in China: minimizing claims or disputes in the contract (Scop14); and managing the job as one whole integrated contract (Scop16). The scope of work within a contract should be properly defined so that claims can be minimized and disputes reduced. It is also recommended that the number of subcontractors be reduced so as to achieve better integration. This is because quality management becomes complex and difficult to implement when many organizations are involved (Love and Irani 2003).

Time management practices

Table 2 shows that a significant time management practice is early acceptance and approval of the schedule by the project team (Time21). This ensures that the project proceeds smoothly as scheduled and time targets are met. Adequate provision of equipment (e.g. computers, plant, machinery) to deliver the service (Time24) is the most important time management practice. A quick and effective response to variations ordered by clients (Time25) is also a key management practice. A quick response usually reduces time loss as a result of variations to the contract (Galloway 2006). The schedule should be monitored by one person (Time26), as having too many people in charge of the schedule could give rise to conflicting ideas and lack of ownership due to diluted responsibilities.

Cost management practices

This study found that there are seven significant cost management practices adopted by foreign firms in China. Most important is for foreign firms to have strong financial strength (Cost37). High quality financial management (Cost32) is important because it helps to maintain positive cash flow and project profitability. Controlling the cost of resources (Cost34) and monitoring project activities to quickly detect and rectify cost overruns (Cost35) are other key project management practices. The findings suggest that foreign firms should set aside adequate financial resources to undertake projects in China, and have headquarters monitoring the China-based project closely (Cost36).

Quality management practices
Foreign AEC firms work for clients that demand quality output (Qty46). To achieve clients' demands, it is important to understand their requirements (Ling *et al*. 2006). AEC firms need to employ high quality managerial (Qty43) and professional staff (Qty44) to boost supervision and control systems. Good quality control and quality management plans (Qty41) must be put in place. These results confirm Ling *et al.*'s (2005a) findings that foreign firms need to offer high quality products and services to demonstrate superior capabilities. Contract requirements must be strictly adhered to (Qty47) and this could be achieved by conducting regular reviews to ensure that firms' output conformed to the requirements in the contract (Qty48). Health and safety management (Qty42) and consideration for environmental impact, sustainability and protection in the delivery of service (Qty49) are also important.

Risk management practices
No significant risk management practices were adopted by Singaporean AEC firms in China. One possibility is that risk is project specific and could not be generalized. Another possible explanation is that these AEC firms did not practise risk management in a formal way.

Human resource management practices
Table 2 shows the importance of providing an adequate staffing level to deliver the service (HRM61). This could be done by employing permanent staff to man the China office. Fabi and Pettersen (1992) also stressed the importance of having adequate personnel in an organizational structure.

Another important practice is to engage Chinese nationals as technical staff or workmen (HRM64). It is cheaper to engage locals than expatriate workers. This further attests to the importance of having local partners from the host country which highlights the nature of international construction whereby many services are supported by the domestic construction industry of the host country. However, because local workers have low skills and are undereducated (Chan *et al*. 1999), it is important to provide them with extensive skills training (HRM65).

Communication management practices
Table 2 shows nine significant communication management practices adopted by Singaporean firms in China. These are by far the largest number of practices under one project management knowledge area, indicating the importance of communication in international construction. The practices adopted include: having more face-to-face communication than written communication (Com71); having high quality communication among team members in terms of communications planning (Com76); quick dissemination of information (Com75) and appropriate generation, collection, dissemination, storage and disposition of project information (Com77). These confirm Harrington *et al*.'s (2000) findings on good communication management. Foreign firms should strive to maintain a good public image and public relations (Com79) by being sensitive to Chinese values and culture. Having good public relations coupled with a good track record lead to a good reputation. AEC firms should adopt a common working language among team members (Com78) so that there would be effective communication. This would help in overcoming the problem of inter-cultural communication in international construction (Victor 1992).

Foreign firms should strive to work with clients (Com72), consultants and contractors (Com73) with whom they had good working relationships in the past. Their behaviour should lead to repeat business (Com74). Long-term relationships engender trust. Individuals who have good working relationships with each other do not exhibit opportunistic behaviour, which yields only short-term benefits (Hill 1990).

Procurement management practices

The results show that partners should not be chosen because they offered low bids through open tenders (Proc86). Latham (1994) criticized the practice of awarding contracts solely based on lowest bid price. The accepted lowest bid does not necessarily equate to actual cost, as contractors' profit is excluded most of the time. Alternative commercial responses of recouping profits will be through variation claims and exploitation of subcontractors' and suppliers' benefits, leading to adversarial relationships. There may also be poor quality performance which eventually increases operational cost. Those who offer low bids may lack technical capability and experience which would constrain growth (Liu *et al*. 2004). It is also important to collaborate with local Chinese firms. A competent local partner would understand better the Chinese environment and help improve a foreign firm's knowledge of the Chinese market (Ling *et al*. 2006).

Integration management practices

The results show that foreign firms should engage staff who are flexible and adaptable to China's political, economic and social landscape (Integ91). This would help in quick understanding of the Chinese business culture and thus reduce their learning curve (Ling *et al*. 2005b). Prioritized objectives should also be communicated to staff (Integ93) so as to allow alignment of objectives. Foreign firms minimized the use of political backing and outside influence on the projects they undertake (Integ95). This suggests that foreign firms in China need to rely on their own merits (e.g. superior capabilities) to secure contracts in China (Ling *et al*. 2006).

CONCLUSION

The literature review of general management practices of foreign AEC firms in China concluded that it is beneficial for foreign firms to enter China; the best market entry modes are entering as wholly owned foreign enterprises and forming project JVs with Chinese firms. The effective business strategies are understanding clients' requirements, and offering superior products and services.

To investigate the project management practices of foreign firms when handling projects in China, a survey of Singaporean AEC firms that had undertaken projects in China was undertaken. Thirty-eight significant project management practices were uncovered. Of these, many practices relate to communication and quality management. These project management practices could serve as a guide to better management of projects in China. No significant practices were found for risk management, suggesting that more should be done to achieve project success.

With increased globalization, AEC firms will undertake projects outside their home countries to survive and grow. The findings may help firms already operating in and those planning to venture into China identify management practices that may help them achieve better project performance.

REFERENCES

Chan, E H W and Chan, A T S (2002) Development of professional system in the construction industry of China. *Journal of Construction Research*, **3**(2), 271–84.

Chan, W K L, Wong, F K W and Scott, D (1999) Managing construction projects in China – the transitional period in the millennium. *International Journal of Project Management*, **17**(4), 257–63.

Chan, A P C, Scott, D and Chan, A P L (2004) Factors affecting the success of a construction project. *Journal of Construction Engineering and Management*, **130**(1), 153–5.

Chen, P and Partington, D (2004) An interpretative comparison of Chinese and Western conceptions of relationships in construction project management work. *International Journal of Project Management*, **22**(5), 397–406.

Chua, D K H, Kog, Y C and Loh, P K (1999) Critical success factors for different project objectives. *ASCE Journal of Construction Engineering Management*, **125**(3), 142–50.

Dai, H C, Cao, G J and Su, H Z (2006) Management and construction of the Three Gorges project. *ASCE Journal of Construction Engineering and Management*, **132**(6), 615–19.

Fabi, B and Pettersen, N (1992) Human resource management practices in project management. *International Journal of Project Management*, **10**(2), 81–8.

Fortune, J and White, D (2006) Framing of project critical success factors by a systems model. *International Journal of Project Management*, **24**(1), 53–65.

Gale, A and Luo, J (2004) Factors affecting construction joint ventures in China. *International Journal of Project Management*, **22**(1), 33–42.

Galloway, P D (2006) Comparative study of university courses on critical-path method scheduling. *ASCE Journal of Construction Engineering and Management*, **132**(7), 712–22.

Gunhan, S and Arditi, D (2005a) Factors affecting international construction. *ASCE Journal of Construction Engineering and Management*, **131**(3), 273–82.

Gunhan, S and Arditi, D (2005b) International expansion decision for construction companies. *ASCE Journal of Construction Engineering and Management*, **131**(8), 928–37.

Han, S H and Diekmann, J E (2001) Approaches for making risk based go/no-go decision for international projects. *ASCE Journal of Construction Engineering and Management*, **127**(4), 300–8.

Harrington, H J, Daryl, R C and Horney, N L (2000) *Project change management – applying change management to improvement projects*. New York: McGraw-Hill.

Hill, C W L (1990) Cooperation, opportunism, and the invisible hand: implications for transaction cost theory. *Academy of Management Review*, **15**(3), 500–13.

Ibbs, C W, Lee, S and Li, M (1998) Fast-tracking's impact on project change. *Project Management Journal*, **29**(4), 35–41.

Jin, X H and Ling, F Y Y (2005) Model for fostering trust and building relationships in China's construction industry. *ASCE Journal of Construction Engineering and Management*, **131**(11), 1224–32.

Jin, X H and Ling, F Y Y (2006) Key relationship-based determinants of project performance in China. *Building and Environment*, **41**, 915–25.

Konchar, M and Sanvido, V (1998) Comparison of US project delivery systems. *ASCE Journal of Construction Engineering and Management*, **124**(6), 435–44.

Latham, M (1994) *Constructing the team*. London: HMSO.

Ling, F Y Y (2004) Key determinants of performance of design-bid-build projects in Singapore. *Building Research and Information*, **32**(2), 128–39.

Ling, Y Y (2005) Benefits that foreigner AEC firms derive when undertaking construction projects in China. *Management Decisions*, **43**(4), 501–15.

Ling, Y Y, Ibbs, C W and Cuervo, J C (2005a) Entry and business strategies used by international AEC firms in China. *Construction Management and Economics*, **23**(5), 509–20.

Ling, Y Y, Ibbs, C W and Kumaraswamy, M M (2005b) Enablers that help foreign AEC firms win construction contracts in China. *Journal of Management in Engineering*, **21**(2), 63–9.

Ling, Y Y, Ibbs, C W and Hoo, W Y (2006) Determinants of international architectural, engineering and construction firms' project success in China. *ASCE Journal of Construction Engineering and Management*, **132**(2), 206–14.

Liu, G, Shen, Q, Li, H and Shen, L (2004) Factors constraining the development of professional project management in China's construction industry. *International Journal of Project Management*, **22**(3), 203–11.

Love, P E D and Irani, Z (2003) A project management quality cost information system for the construction industry. *Information and Management*, **40**, 649–61.

Luo, J (2001) Assessing management and performance of Sino-foreign construction joint ventures. *Construction Management and Economics*, **19**, 109–17.

PMI (Project Management Institute) (2004) *A guide to the project management body of knowledge (PMBOK guide)*. 3ed. Newtown Square: Project Management Institute.

Victor, D A (1992) *International business communication*. New York: Harper Collins.

ANALYSING TENDER SELECTION USING A GEOMETRIC GRAPH ANALYSIS (GGA) APPROACH

Kwo-Wuu Wang[1] and Wen-der Yu[2]

[1]*Department of Civil Engineering, Chung Hua University, No.707 Sec. 2 WuFu Rd. Hsinchu, 300 Taiwan*
[2]*Institute of Construction Management, Chung Hua University, No.707 Sec. 2 WuFu Rd. Hsinchu, 300 Taiwan*

As projects and products become more and more versatile and complex, procurement approaches have also diversified. The traditional competitive bidding method based on lowest price (also named lowest tender, LT) usually results in high competition and low quality. As a result, the most advantageous tender (MT) was brought into the Government Procurement Law (GPL). After several years of practice, the public procurement agencies are still wondering why and how to select LT or MT. This paper proposes a geometric graph analysis (GGA) model adopted 2-D analytical graph for modelling the two most important factors in procurement, i.e. price and quality to develop an analytical tool for answering the above-mentioned questions. It is found that the proposed GGA provides not only a theoretical framework for analysis of suppliers'/contractors' behaviours during the procurement process, but also an efficient tool for procurement strategy planning.

Keywords: lowest tender, most advantageous tender, procurement policy, tender selection.

INTRODUCTION

As projects and products become more and more versatile and complex, procurement approaches have also diversified. The traditional competitive bidding method based on lowest price (also named lowest tender, LT) usually results in high competition and low quality, which is not sufficient for selecting the most appropriate tender in the diversified procurement requirements nowadays. As a result, the most advantageous tender (MT) was brought into the Government Procurement Law (GPL) in 1999 in Taiwan. In contrast to LT, the MT selects the tender that is the most advantageous to the project owner. After several years of practice, the public procurement agencies are still wondering why and how to select LT or MT, the pros and cons of LT and MT, and the reason for poor procurement. It is very desirable to develop an analytical tool for answering the above-mentioned questions.

In this paper, a geometric graph analysis (GGA) approach is proposed to: (1) explore the price effect of LT in procurement; (2) analyse the different procurement methods such as LT and MT; and (3) compare the efficiency of tender selection between LT and MT. The proposed GGA is an analytical approach that expresses two most important factors, price and quality, in a Cartesian Axis. The behaviours of the demander (buyer or project owner) and the supplier (contractor) are modelled and analysed with GGA. In order to demonstrate the applicability of the proposed GGA,

[1] wangkwo4@yahoo.com.tw.

case studies of real world procurement examples are conducted. The rest of this paper is presented in the following manner: the related researches are reviewed first followed by definitions of terms utilized in the paper; then, the theoretical framework of GGA is proposed; application to real world procurement cases is demonstrated in the fifth section; finally, discussions and conclusions are described.

LITERATURE REVIEW

According to the definitions of Taiwan GPL (Article 52), the methods of contract awarding include LT and MT (Wu 2005). The LT method assumes that plans and designs are detailed and clear enough, so that the contractors won't make mistakes during cost estimation. As a result, the contractor with best management capability can offer the service or product with lowest price and thus wins the bid. According to Gransberg and Ellicott (1996), LT creates a business relationship based on a single factor, price. They also found that LT can simplify the process of selection, solicitation preparation and tender review. It is assumed that the quality of LT can be assured via auditing and inspection procedures (Nissen 2006). Such presumption however has not worked out in practice under the GPL in the past seven years. Kashiwagi and Al-Sharmani (1997) pointed out the weakness of LT: that it favours contractors who can provide minimum quality and performance. In LT, no credit is given to a contractor who provides more skilled craftspeople, better construction methods and higher quality materials. Nissen further points out that LT makes flawed assumptions, encourages cost-cutting and underperformance and does nothing to screen out unscrupulous contractors (Nissen 2006).

The US Federal Acquisition Regulation (FAR) 15.605 states: '(in addition to price) … quality also shall be addressed in every source selection' (US Government 1994). In the same article, it also states: 'While the lowest price or lowest total cost to the government is properly the deciding factor in many source selection, in certain acquisitions the government may select the source while proposal offers the greatest value to the government in terms of performance over and above the minimum acceptable level will enhance mission accomplishment and be worth the corresponding increase in cost.' The above regulation has led to the most advantageous tender (MT), which shifts the competition point from price to quality. The 'quality' is defined as the merits that can improve utilities of the buyer/project owner. The above-mentioned merits may include technical advantages, previous performance, safety practice, local experience, worker training and price. In many cases of MT, the price is fixed, and thus the most advantageous is determined by the best quality offered by the suppliers/contractors. Since the fixed price of the project should be developed early, it is found that change orders and litigation were reduced dramatically in MT (Nissen 2006). According to Taiwan GPL (Article 52), the MT method can only be adopted when a procurement contract may result in discrepancies in technology, quality, function, efficiency or the implementation of commercial terms, etc., as it is carried out by different suppliers/contractors (Wu 2005).

Kashiwagi (2003) proposed a 2-D figure (as shown in Figure 1) to model the competition and performance of contractor selection methods in the construction industry. Owing to increasing competition worldwide, quadrants I and Π in Figure 1 are becoming more and more popular for the construction industry. Quadrant I is related to low performance and high competition, which is closed to the LT. Quadrant II is related to high performance and high competition, which is closed to the MT.

Even though subjective comments were found in the literature, an analytical tool for analysis of contractor selection methods is still not available.

DEFINITION OF TERMS

For the convenience of model construction of the proposed GGA, the abbreviations and symbols adopted in this paper are defined in this section and summarized in Table 1. Note that the abbreviations and symbols with a superscript ‘*’ denote the theoretical curves or ranges that the suppliers/contractors do not participate in the bidding of public procurements; while the ones without ‘*’ denote the curves or ranges that the suppliers/contractors participate in bidding of public procurements.

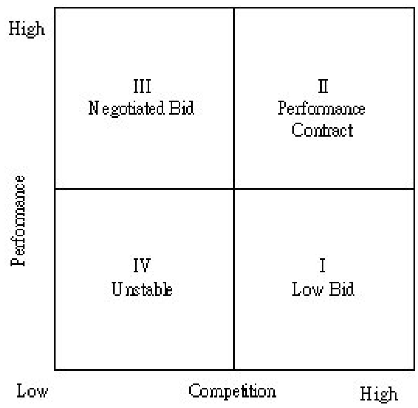


Figure 1: Constructor selection in construction industry (Kashiwagi 2003)

Table 1: Definition of abbreviations and symbols

Abb./symb.	Definition
point (x , y)	Point (x, y) represents a tender with a specific set of price and quality related to the service/product provided by the supplier/contractor under rational basis.
Price	The bid price offered by a supplier/contractor in conformity with the requirements of the buyer/project owner under rational basis.
Quality	A broad definition of quality/merit that improves the utilities of the buyer/project owner including everything except the price during the trade.
P_B	The ceiling price of buyer/project owner, usually relates to the buyer’s/project owner’s budget.
P_L	The bottom price (the lowest allowable price) set up by the buyer/project owner in order to avoid poor quality of obtained service/product.
P_i	A certain price offered by the supplier/contractor lying between P_{MIN} and P_{MAX}, i =0, 1…n. P_i can also be regarded as any possible price that the buyer is willing to pay, thus, P_i will lie between P_L and P_B.
LT	The lowest tender
MT	Most advantageous tender
SS*	The curve of all possible tenders in the free market without constraints of GPL
SS	The curve of all possible tenders awarded by the principle of contract awarding of GPL
HQ*	The curve of the highest quality tenders under rational price in the free market
LQ*	The curve of the lowest quality tenders under rational price in the free market
HQ	The curve of the highest quality tenders awarded by the principle of contract awarding of GPL
LQ	The curve of lowest quality tenders awarded by the principle of contract awarding of GPL
Q^*_{MAX}	The highest quality tenders of service/product in conformity with the requirements of the buyer/project owner in the free market
Q^*_{MIN}	The lowest quality tenders of service/product in conformity with the requirements of the buyer/project owner in the free market
Q_{MAX}	The highest quality tenders of service/product in conformity with the requirements of

	the buyer/project owner in the public procurement
Q_{MIN}	The lowest quality tenders of service/product in conformity with the requirements of the buyer/project owner in the public procurement
P^*_{MAX}	The highest rational price tender in the pool of Q^*_{MAX}
P^*_{MIN}	The lowest rational price tender in the pool of Q^*_{MIN}
P_{MAX}	The highest rational price tender in the pool of Q_{MAX}
P_{MIN}	The lowest rational price tender in the pool of Q_{MIN}
W*	The pool of suppliers/contractors in a free market, which is selected by the buyer/project owner. The region matches buyer's/project owner's requirements and is encircled by curve HQ*, LQ*, Q^*_{MIN}, and Q^*_{MAX}
W	The pool of suppliers/contractors selected by the public buyer/project owner. The region matches the public buyer's/project owner's requirements and is encircled by curve HQ, LQ, Q_{MIN}, and Q_{MAX}

THEORETICAL FRAMEWORK OF GEOMETRIC GRAPH ANALYSIS (GGA)

Basic model

As shown in Figure 2, the proposed GGA model is a two-dimensional graph with the X-axis presenting the broadly defined 'quality' and the Y-axis presenting the 'price' of the service/product provided by the contractor/supplier. There are two curves in Figure 2: (1) LQ* – the lowest quality tenders under rational price in the free market; (2) HQ* – highest quality tenders under rational price in the free market. Both of the curves are subject to the rational price set up by the contractor/supplier in conformity with the requirements of the buyer/project owner. Every point (x, y) in Figure 2 represents a tender with a specific price and quality related to the service/product provided by the supplier/contractor. On the price axis (Y-axis) there is an upper-bound on curve LQ*, P*MAX, which stands for the highest rational price tender of the lowest quality service/product providers; similarly, there is a lower-bound on curve HQ*, P*MIN, which stands for the lowest rational price tender of the highest quality service/product providers. The upper-bound and lower-bound are also found on the quality axis (X-axis), which are Q*MAX, and Q*MIN respectively. In constructing the GGA, two assumptions should be made beforehand:

Assumption 1: rational price

The rational price is set up by the supplier/contractor based on the requirements defined by the buyer/project owner and efforts and costs he/she must spend to meet the requirements.

Assumption 2: continuity of curve

It is assumed that in the considered range of GGA, there is at least one supplier mapping to a tender point (x, y). In the real world, the tenders on the curves in the GGA graph may not be continuous but discrete.

It is noted that the 'quality' in GGA is the broadly defined quality that may improve the utilities of the buyer/project owner apart from price (Fan 1998). On the other hand, the 'price' is determined on a rational basis, which generally takes into account all influential factors such as direct cost, indirect cost, profit margin, competition situation, cost and fixed price of product performance, market price and competitor, etc. It implies that the rational price is closely related to the quality; as the quality increases the rational price increases accordingly (Chen 1994). Such relationship is shown in Figure 2; there HQ* is a concave curve, which means the marginal increase of quality is less than the increased cost. Similarly, LQ* is a convex curve, which means the marginal increase of quality is greater than that of the cost. Such definition conforms to that of value engineering (VE), where the marginal quality increase is less than the increased cost in the high quality area (meaning 'low value' product or 'redundant quality'). Moreover, the HQ* curve is always right and lower to the LQ*. It means that, for the same quality level, the tender on the HQ* is always less expensive than that on the LQ*.

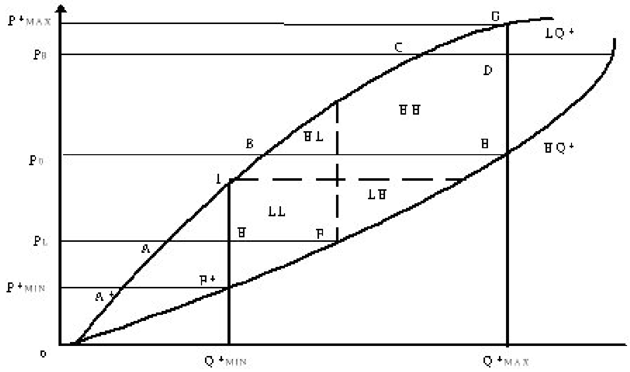


Figure 2: GGA graph

Supplier area (W, W*)

The region GEF*I in Figure 2 bounded by curves HQ*and LQ* represents the area where the potential qualified (met with the buyers'/owners' lowest requirements on quality, Q*MIN) tenders which is the biggest assembling of buyers' considered selection, are distributed. This potential tender area is defined as the 'Supplier area in the free market (W*)'. The region DEFHIC in Figure 2 represents another set (W) of potential qualified tenders under the regulation of GPL. DEFHIC is bounded with the ceiling price of buyer/project owner (PB) and bottom price set up by the buyer/project owner (PL). Under special conditions that PL = P*MIN and PB = P*MAX, W is equal to W*. There are four regions in W*: (1) low price/low quality area (LL); (2) low price/high quality area (LH); (3) high price/high quality area (HH); and (4) high-price /low-quality area (HL). The tenders located in LH are the best candidates for selection in procurement. LL and HH are second choices, while tenders in HL are those that should be avoided by the buyers/project owners.

Tender classification and supplier/contractor selection

Before taking into account the competitive bidding, let us consider a certain price, P0, all tenders on line $\overline{BE}$ are potential candidates for selection. While relaxing single price point P0 to a price range [PL, PB], the best choices are tenders on curve EF and the worst choices are on curve AC. In practical application, the distance between LQ* and HQ* or their shapes on the graph will be different according to the different procurement items. The buyer/project owner often classifies the procurement items into A, B, C classes (see Figure 3) according to the amount in stock, quantity for procurement, the levels of price or value (Fan 1998). The items in Class A mean small quantities, high prices and great value products, which is the 'important minority' in procurement, e.g. high-tech equipment. In contrast, items in Class C mean large quantities and low prices, the insignificant majority in procurement, e.g. standard products.

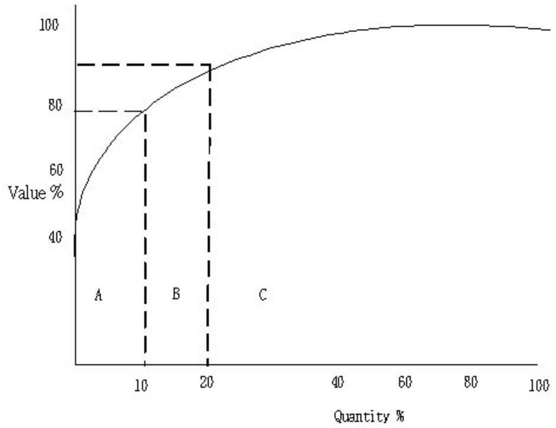


Figure 3: Classification of procurement items

In practical tender selection, Classes A and B require more attention than Class C. The requirements of security, reliability, post-sale service, etc., are higher. The flexibility of Classes A and B is also greater than that of C. As a result in procurement of tenders in Classes A and B, the ranges of [P*MIN, P*MAX] and [Q*MIN, Q*MAX] are wider than that of Class C. The shapes of curves LQ* and HQ* in procurement of tenders in Classes A and B are relatively high, wide and steep, such as those shown in Figure 4. The typical shape of curves LQ* and HQ* in procurement of tenders in Class C is shown in Figure 5.

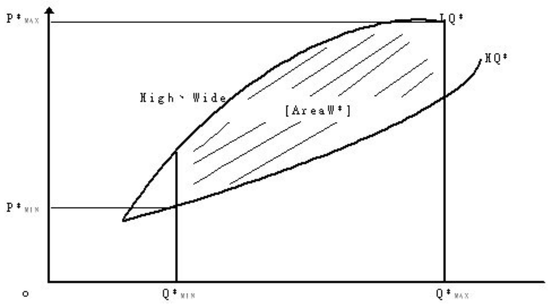


Figure 4: Typical GGA graph of Classes A and B

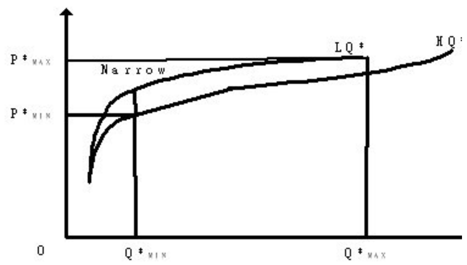


Figure 5: Typical GGA graph of Class C

In this paper, procurements of tenders in Classes A and B are considered. It is also assumed that the curves LQ* and HQ* intersect each other on the origin.

In selection under the ‘performance specification’, the range between curves LQ* and HQ* is also relatively wide compared with those of the technical (prescriptive or descriptive) specifications. It is because that the technical specifications specify the quality of procured items more precisely. Usually, the procurements are performance-based for tenders in Classes A and B, and technical-based for those in Class C.

Adaptation for practical application

The GGA model proposed in this paper is a theoretical framework for procurement analysis. It needs to be modified before application to a real world situation. Before the modification, one assumption (Assumption 3) should be made first:

Assumption 3: sequential order of quality

It is assumed that all tenders in the GGA graph are discriminable in the orders of their quality levels, where the Transitive Law holds. That is, any three different tenders (A, B and C) in procurement can be ordered according to their quality levels. If the quality of tender A is better than that of tender B and the quality of tender B is better than that of tender C, then the quality of tender A is better than that of tender C.

In practical application, a GGA graph should be constructed like the one shown in Figure 6. Based on Assumption 2, the curves in the GGA graph are assumed to be continuous. The tender price and quality information collected from the marketplace are finite. The dots ‘*’ in Figure 6 represent the potential suppliers’ tenders in the marketplace. The upper and lower frontiers of data envelope form the LQ* and HQ* in the GGA graph. Interpolation and extrapolation can be employed for continuous curve construction. Sometimes, ordering of the quality of tenders is difficult. Semi-quantitative methods, such AHP (Saaty 1980), can be adopted for quality ordering. For example, as shown in Figure 6, if the buyer is willing to purchase the item within a budget of $100, theoretically the buyer would never select the supplier with a $120 offer. Only when the supplier lowers his/her price to $100 (in other words, cuts the price by $20) will it be selected by the buyer.

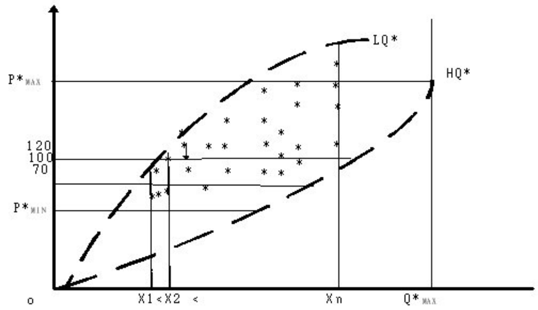


Figure 6: Discrete GGA curves and tenders in practical application

VERIFICATION WITH REAL WORLD CASES

The theoretical model of GGA proposed in the previous section needs to be verified with real world cases. In this section, the diesel engine procurement is considered for study. Take the quotations of diesel engine generators of Americas Generators from the Internet (for example www.GoPower.com). Consider the power rate (KW) of the generator as the quality (X-axis) and the Y-axis relates to its price; two scatter plots are obtained as shown in Figure 7 (20~100 KW) and Figure 8 (50~250 KW).

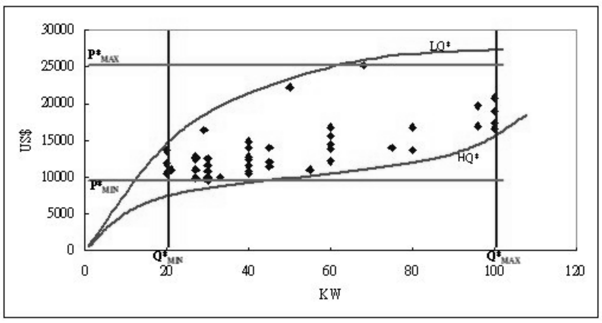


Figure 7: GGA graph for 20-100 KW diesel engine generators

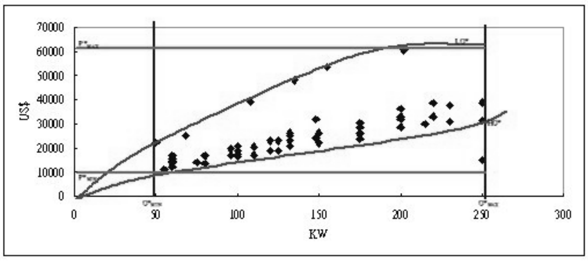


Figure 8: GGA graph for 50-250 KW diesel engine generators

It is found from Figure 7 and Figure 8 that both graphs are in conformity with the typical shapes of GGA graphs. All parameters of GGA can be identified in these graphs. The parameter vector [P*MAX, P*MIN, Q*MAX, Q*MIN] of the GGA graph in Figure 7 is [$25 198, $9999, 100 KW, 20 KW]; the same vector for the GGA graph in Figure 8 is [$60 688, $10 999, 250 KW, 50 KW]. It is also found that the shape of the GGA graph in Figure 7 is similar to that of Figure 5 (Class C), while the GGA of Figure 8 is similar to Figure 4 (Classes A and B).

It is noted in both graphs that generators with the same quality (generation power) are priced differently. There may be some other factors (e.g. durability, weight, noise, fuel consumption rate, etc.) not included in the quality dimension here. The theoretical framework of GGA is verified in the both of the above cases.

APPLICATIONS OF GGA

In this section, the applications of the proposed GGA to procurement analysis are described. The analyses include: (1) the price effect of the lowest tender (LT) on quality; (2) the selection of tenders; and (3) the appropriate contract awarding zone.

Price effect of the lowest tender on quality

It is conceived that under the LT method the suppliers/contractors tend to lower prices in order to win the bid. Based on the theory of GGA, the quality of service/product may also decrease accordingly as the price is decreased. If the price is decreased to the direct variable cost (VC), which refers to production and marketing-related direct cost, the quality of product will be significantly affected by price reduction. In contrast, the government's pollution control and the standard of security requests or the goals of business can make the price rise, shown as in Figure 9 (Chen 1994).

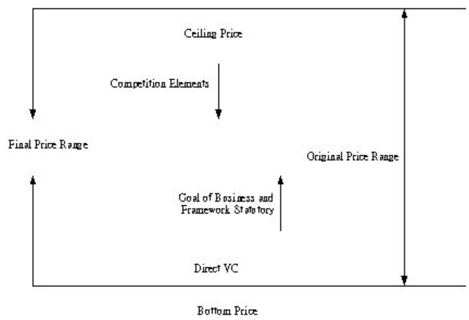


Figure 9: The behaviour of suppliers in response to price reduction

Effect on supplier area (W* and W)

After price reduction under the regulation GPL, the GGA graph is reshaped. The ideal shape of the GGA graph for LT is shown in Figure 10, where the original graph is shifted down (from graph K to graph V). For convenience of comparison, the graphs K and V are merged to graph O in Figure 11. It can be seen that the scope of W is smaller than W *. Because of the high quality regions are expelled due to price reduction.

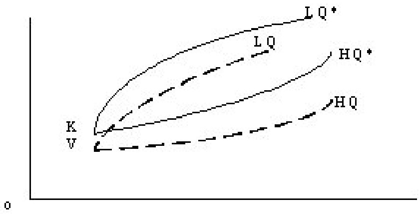


Figure 10: Ideal GGA graph shift in LT under price competition

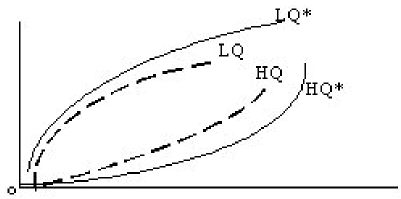


Figure 11: Actual GGA graph in LT after price reduction

Effect on tenders of Class C

In Figure 12, P*MAX is reduced to P MAX. It is not difficult to find a tender B on LQ with the same quality as C on LQ*. For some price-indifferent tenders where price and quality are little different in Classes A and B, the effect is similar; such effect is shown in Figure 13.

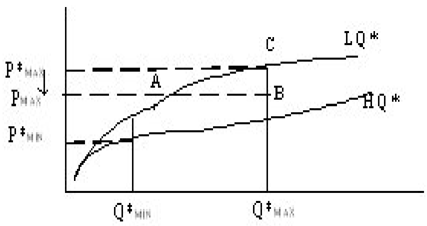


Figure 12: Price reduction effect on the tenders in Class C

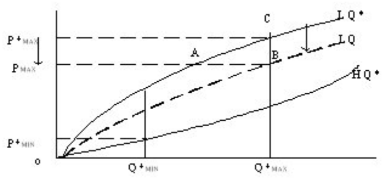


Figure 13: Price reduction effect on the price-indifferent tenders in Classes A and B

In either Figure 12 or Figure 13, the price reduction effect on quality is not significant. This is in conformity with the preconception that LT is suitable for tender selection of Class C (and also for price-indifferent tenders in Classes A and B).

Effect on typical tenders of Class A and B

For the typical tenders in Classes A and B (with high wider ranges between curves LQ* and HQ*), the price reduction will shift the curve HQ* to curve HQ (the Q*MAX is reduced to Q MAX) in Figure 14 and cause loss of suppliers in the area BCD (where the high quality/high price suppliers are unwilling to reduce their quality and price).

After price reduction, the resulting supplier area W is much smaller than W*. The highest quality falls from Q*MAX to QMAX, namely suppliers in region AEBC are expelled due to price reduction. The greater the reduction of price, the more loss of quality. As a result, the LT is not suitable for tender selection in Classes A and B.

Moreover in Figure 14, suppliers in AEDB may be able to reduce their prices to the lowest rational prices without reducing the quality. Among those, suppliers in region AE'D' are more likely to lower their prices to PMAX or lower, but suppliers in region EDBD'E' may be expelled due to less flexibility on price. Because of the AE'D' quality compared to EDBD'E' is lower, it has high price competition. The quality of E' compared to D' is lower, similarly has high price competition, so the position is left and high. The quality of D' is relatively high, has the lower competition, therefore the position is right and lower. Thus below the region of curve E'D' will have high competition.

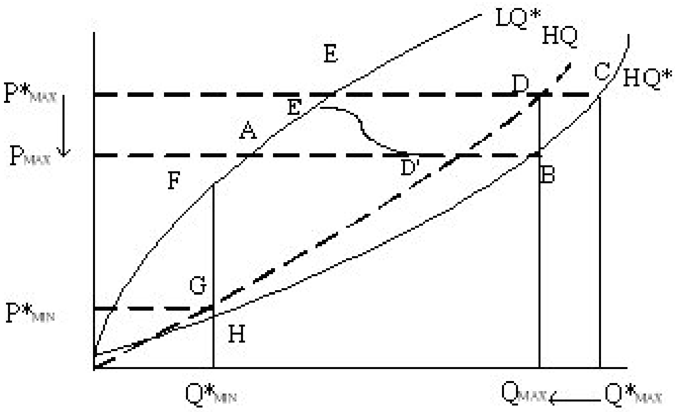


Figure 14: Price reduction effect on typical tenders in Classes A and B

SELECTION OF TENDER

Assume that the buyer is willing to purchase an item with price Pi, and the information of market condition is offered completely, then P*MIN ≤ Pi ≤ P*MAX. According to Assumption 2, no matter which selection method is adopted, there will be a tender to be selected in W. Figure 15 shows that within the budget of the buyer, every possible price Pi will map to the curve SS. Owing to price competition, SS tends to be closed to curve LQ. The basic principle for an efficient tender selection strategy is to force the SS to be closer to curve HQ.

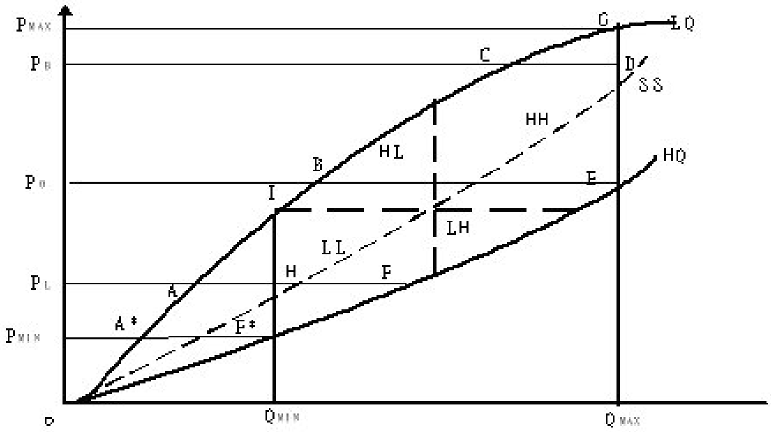


Figure 15: Tender selection curve (TSC)

Contract awarding zone (CAZ)

The proposed GGA can be used for preplanning for the contract awarding zone (CAZ) for procurement in order to select the most appropriate tender. The following discussion is with regard to Figure 15. In the area of HL and LL of Figure 15, the quality index is ‘Low’ and the price index is either ‘High’ or ‘Low’. Thus, when LT is applied, price will govern the competition result, rather than quality. Suppliers should reduce their prices in order to increase the probability of winning the award. Therefore LT is more likely to award to suppliers located in areas LL and HL than MT. On the contrast, the MT is more likely to award the contract to suppliers located in areas LH and HH.

The GGA for tenders in Class C (most are standard services/products) is characterized as: (1) with smaller disparity both from QMIN to QMAX and from PMIN to PMAX; (2) the market information is clear and open; (3) buyer's estimation is accurate, thus is more suitable for LT.

If the procured items belong to Classes A and B with greater quality and price ranges in the GGA graph, the MT will be best choice. Because the procurement items in Classes A and B are greater in disparity from PMIN to PMAX and QMIN to QMAX, improvement of quality is greater than that in Class C.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, a new analytical tool for analysis of both public and private product/service/project procurement processes is proposed, named geometric graph analysis (GGA). The proposed GGA model adopts a 2-D analytical graph for modelling the two most important factors in procurement, i.e., price and quality. Similar to the demand-and-supply diagram in economics, the GGA graph is employed to model the behaviours of suppliers/contractors during the procurement process. The theoretical framework of the proposed GGA model is described in detail. Real world procurement data are employed to verify the proposed GGA model. Potential applications of the proposed GGA model are also discussed in depth in three areas: (1) analysis of the price effect of the lowest tender (LT) on quality; (2) analysis the efficiency of tender selection with LT and MT; and (3) analysis of the appropriate contract awarding zone.

It is concluded that the proposed GGA model not only provides a theoretical framework for analysis of suppliers'/contractors' behaviours during the procurement process, it is also an efficient tool for procurement strategy planning. Further demonstrations and applications adopting the GGA model should be conducted in the future to fully exploit its benefits and functions. Application of GGA to procurement strategy planning is a valuable area for future research, too.

REFERENCES

Chen, M-H (1994) *Pricing and profit management*. Taipei, Taiwan: Tsing Hwa Technological Publisher Inc. (in Chinese).

Fan, M (1998) *Management of logistics*. Taipei, Taiwan: Li-Min Publisher Inc. (in Chinese).

Gransberg, D D and Ellicott, M A (1996) Best value contracting: breaking the low-bid paradigm. *AACE Transaction*, VE&C, 5.1–5.4.

Kashiwagi, D T (2003) Identify true value of construction. Paper presented at the 47th Annual AACE International Meeting, Orlando, FL. Track IT.03 on CD.

Kashiwagi, D T and Al-Sharmani, Z (1997) A performance-based procurement system used by the State of Wyoming. *Cost Eng.*, **39**(12), 37–41.

Nissen, B (2006) *Best value in publicly funded projects: contractor selection in two county GOB projects*, Research Report, Center for Labor Research & Studies (CLR&S), Florida International University, FL, USA.

Saaty, T L (1980) *The analytic hierarchy process: planning, priority setting, resource allocation*. New York: McGraw-Hill.

US Army Corps of Engineers (1990) *Procedures manual for formal source selection*, Technical Report DD Form 1131, Sacramento, CA, USA.

US Government (1994) Section 15.605, *Federal Acquisition Regulation*. Washington, DC: Government Printing Office.

Wu, C J (2005) Government Procurement Law – Article 52. *In*: Public Construction Commission *Government Procurement Laws*. Taipei, Taiwan: Public Construction Commission.

IMPLICATIONS FOR DESIGN AND BUILD CONTRACTORS BIDDING IN PUBLIC–PRIVATE PARTNERSHIP CONSORTIUMS: AN AUSTRALIAN PERSPECTIVE

Denny McGeorge[1], Marcus Jefferies, Katie Cadman and Chen Swee Eng

School of Architecture and Built Environment, Faculty of Engineering and Built Environment, The University of Newcastle, University Drive, Callaghan, NSW 2308, Australia

The term design and build (D&B) is a well-established description of a procurement method in which the roles and responsibilities of the various stakeholders are clearly defined. The advent of public–private partnerships (PPPs) brings a new opportunity for design and build contractors with the concomitant challenge associated with bidding as a member of a private sector consortium with numerous stakeholders. The work described in this paper is based on an ongoing Australian Research Council (ARC) research project that is investigating the costs and the allocation of risks during the bidding process for PPPs. In the course of this research we have explored the implications for design and build contractors bidding for social (as opposed to economic) PPP projects. The conventional wisdom has been to assume that there is little difference between bidding for a conventional design and build contract as compared with submitting a design and build bid as part of a total PPP bid; however the results of our study indicate that there are subtle, and in some instances, significant differences. By way of placing the Australian experience in context, the paper also traces the emergence and growth of social infrastructure PPPs in Australia.

Keywords: bidding costs, design and build (D&B), design and construct (D&C), public–private partnership (PPP), tendering costs.

BACKGROUND

The genesis for this Australian Research Council (ARC) collaborative research project came from the private sector where there would appear to be a widely held view that public private–partnerships (PPPs),[1] particularly with respect to hard social infrastructure projects[2] are partnerships in name only. This line of argument is advanced by Curnow *et al*. (2005) who argue that there is a strong body of opinion to support the contention that current social infrastructure projects in Australia are not true partnerships and there is a clear need to reduce the ‘tokenism’ of Australian PPPs. They argue that the public sector needs to make PPPs more attractive to the private sector and clarify the identification of risk in order to transfer more responsibility to the private sector. This issue is supported by recent industry criticism of PPPs concerning the ‘narrowness’ of the scope of work that is offered to the private sector.

In reality, in many instances, in the view of Curnow, PPP project costs relating to finance, building design, construction, maintenance and waste management amount to less than 15% of the total life cycle cost of the enterprise. As a result, the private sector may be deterred by the high transaction costs of social PPPs, which offer only a

[1] denny.mcgeorge@newcastle.edu.au

marginal increase in scope of business opportunity. This is in direct contrast to opportunities that are available in the much lower cost-to-bid ratio of more standard procurement models or in hard economic PPP projects where the revenue stream from, say, a freeway tollway has a substantial and clearly defined internal rate of return. There is evidence from our own research to support the view that a number of private sector players are either withdrawing from social PPP projects completely or are being highly selective because of the unattractiveness of the projects on offer.

In summary, there is a body of opinion among private sector consortium bidders for hard social infrastructure PPP projects that they are being hit by what might be described as a 'double whammy effect' where the financial rewards are less and the operational demands are more complex than for hard economic PPP projects. Not withstanding this situation, the number of proposed hard social PPP projects in Australia is on the increase and there are a number of private sector players who are willing to bid in this environment.

EMERGENCE OF SOCIAL PPPS

As part of the research a compilation was made of all PPP projects from 1986 onwards undertaken to date in Australia (Table 1). This compilation includes all projects listed by Jones (2003) and Duffield (2005) together with (as far as is known) all PPP projects up to May 2006. The data illustrate (with a few exceptions) that the application of the PPP approach to hard social infrastructure PPPs is a relatively recent trend. However, many of the projects currently under consideration in 2006 are for hard social PPP projects. Whether or not these projects progress to fruition will largely depend on the perceived risks and returns to both the public and private sectors. Table 1 demonstrates the increasing number of social PPPs either in the pipeline or under consideration in Australia.

Table 1: Total break-up of PPP project types across the states

Year	**FED**		**ACT**	**NSW**			**NT**		**QLD**			**SA**		**TAS**	**VIC**			**WA**		**Total**
	E	S	S	E	S	U	E	U	E	S	U	E	S	S	E	S	U	E	S	
1988				1					1											**2**
1992				3																**3**
1993					1										1					**2**
1995													1							**1**
1996				2	2											2				**6**
1997				2					1							2			1	**6**
1998										1						1			1	**3**
1999				3								1			1					**5**
2000				2												1		1		**4**
2001				1	1				1				1						1	**5**
2002				1		1									1	1	1			**5**
2003	1			2	2			1								2				**8**
2004					2	1								1			1		1	**6**
2005	1	2		6	3	1	1		6	2			1		5	3	1		1	**33**

2006*			1	8	13	1			1	3	1		3	1	1	7	3		1	**44**
Total	**2**	**2**	**1**	**31**	**24**	**4**	**1**	**1**	**10**	**6**	**1**	**1**	**6**	**2**	**9**	**19**	**6**	**1**	**6**	**133**

Notes:
*A number of the projects listed in the table for the year 2006 are under consideration and may or may not proceed as a PPP.
E Hard economic infrastructure.
S Hard social infrastructure.
U Urban renewal & associated infrastructure.

PRACTICAL ISSUES WITH HARD SOCIAL PPPS

As previously stated the trigger for the research project was the view expressed by private sector players that the current high cost of transaction fees incurred in bidding for hard social PPPs was acting as a deterrent to bidders and that in many cases the concept of partnership was token rather than genuine (Curnow *et al*. 2005). Curnow argues for a broadening of the scope of work to make PPPs more attractive to the private sector whereas Blood (2005) argues more for a transfer of responsibility to the private sector rather than the scope of work per se (although both arguments, if accepted, would perhaps have the same result). Blood’s proposition is that:

> The Government perception of PPPs is that this is private funding for public infrastructure. But this misses the point: PPPs are a shift of responsibility, not of funding. They motivate all parties to take responsibility for their actions and delivery, making projects more accountable and measurable.

In support of his argument Blood makes the case that PPPs should not be used as a scapegoat for Government-led finance or staff cuts and changes but rather should be seen as an opportunity not to reduce staffing but to make staffing more efficient through a better infrastructure for delivery. There are certainly a number of critics, including the trade unions, who would not subscribe to this point of view

These issues, while not necessarily unique to social PPPs, are perhaps more acute than for economic PPPs. If a comparison is made between a large teaching hospital as an example of a social PPP and a tollway as an example of an economic PPP then the contrast in terms of complexity of operation and interaction between the private sector operator and the users is quite marked. In the hospital situation staff costs will represent at least 90% of the total annual operating costs whereas in a tollway staff costs are minimal with the largest item of expenditure being on maintenance. While both types of PPP do carry a number of risks (to both the public and private sectors) the risk potential over the operating period would appear to be greater in social PPPs than for economic PPPs.

THE RESEARCH PROJECT

As previously stated, the initiative for the research project came from the private sector. Our industry collaborators are (with one exception) D&B companies who, in turn, are part of larger holding companies. Our dialogue has, in the main, been with the D&B sector. It has at times been difficult to differentiate between responses that relate specifically to D&B issues and evidence that relates to issues affecting the consortium as a whole. The network of relationships between the various consortium members during the bidding process is highly complex. Although contractually the bid vary quite markedly. Care has to be taken in discussions with industry players in establishing the role of a particular organization in a PPP consortium since not only does this role vary from project to project, but also individuals within one organization can have more than one role in preparing the project bid. In this instance, our research is primarily concerned with PPPs as seen from a design and build contractor's perspective. However, key personnel can have responsibilities in both design and build and facilities management (FM) and in some cases also be a member of the SPV team. A typical consortium structure is illustrated in Figure 1. Additionally, care has to be taken in distinguishing between the cost of bidding and the bid price as problems can and do arise when the cost of preparing the bid is confused with the bid price. During our interviewing process we found that respondents often discussed both the consequences of winning a bid and undertaking the D&B contract under consortium conditions together with the consequences of losing a bid and having to absorb the bid costs into the next round of bidding. We have attempted to make a clear distinction between these quite two different sets of circumstances, but cannot guarantee always to have done so.

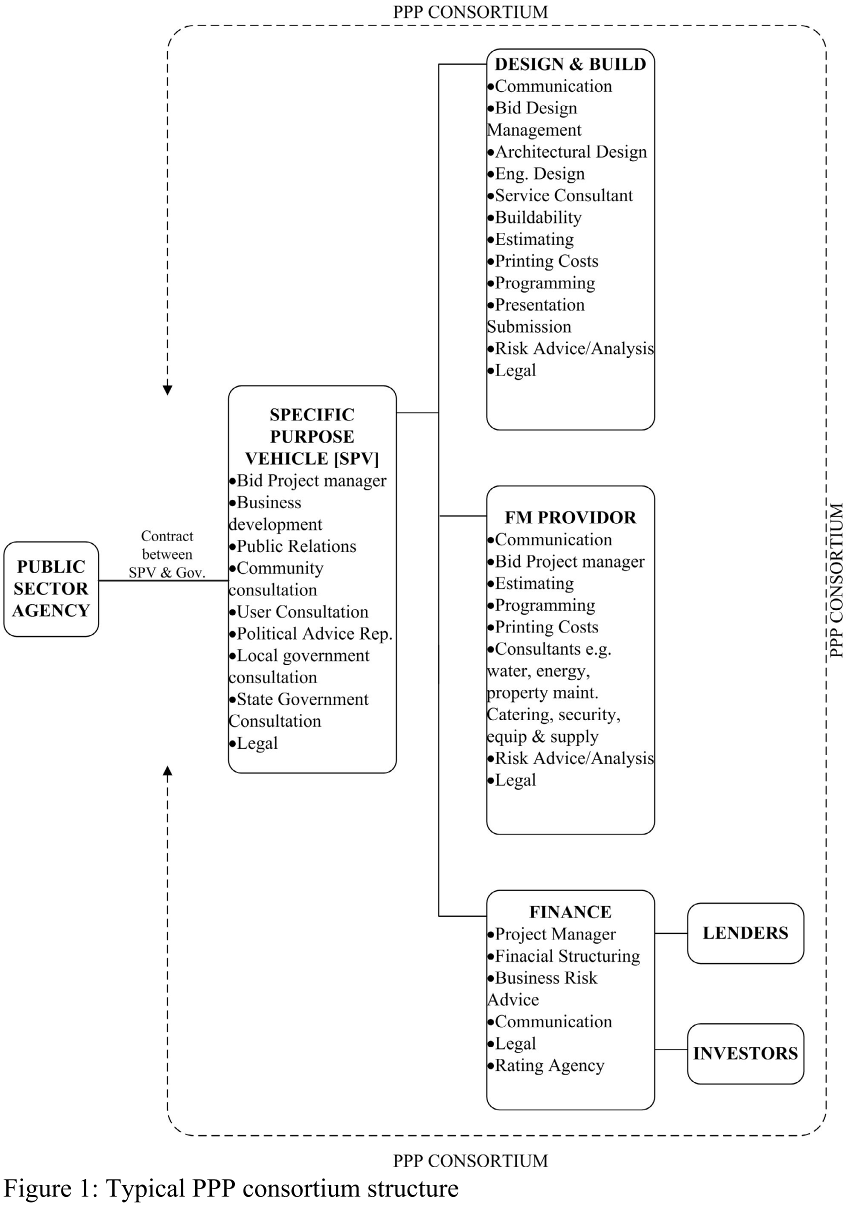


Figure 1: Typical PPP consortium structure

RESEARCH APPROACH

The basic premise underpinning this component of our research project was that there were underlying differences for D&B contractors bidding in a PPP environment as opposed to a standard D&B contractual relationship and that the most appropriate method of determining these differences was through interaction with senior industry experts whose views were taken as representing a distillation of the opinions of major players in the field. This expert opinion approach is, in our view, justified both in terms of research methodological grounds and also on pragmatic grounds given the sensitive and confidential nature of the data. The full research methodology is illustrated in Figure 2.

Review of recent reports of the industry
Comprehensive review of related literature and critical industry reports used to generate list of major challenges facing Australian construction PPP industry. Analysis identified key issues and themes.

↓

Industry Reference Group
Industry Partners made up of three construction groups representing a substantial sector of PPP contractors in Australia. Each Industry Partner nominate 2 experts experienced in PPP bidding and part of consortium.

↓

Research Method
Semi-structured interviews and workshops conducted with nominated experts & support staff. Interviews conducted over series of stages to establish dialogue between researcher and participants and gain both qualitative and quantitative data. Information gained from interviews establishes case studies on various PPP projects.

Quantitative
Quantitative data collected to establish the costs of bidding for PPP projects.

Qualitative
Semi-structured interviews focus on key themes identified from literature review. Industry partners views and key concerns documented & used to corroborate bid costs.

↓

Case Studies
Compilation of case studies based on analysis of information provided by industry partner's nominated experts. Cases studies consist of current major social infrastructure projects procured under the PPP procurement model.

↓

Analysis of Data

Quantitative
Qualitative data of bid cots analysed using descriptive statistics.

Qualitative
Qualitative data analysed using combination of content analysis and grounded theory to group the findings.

↓

Draft Report & Industry Workshop
Research findings compiled into draft report and validated as an on-going process via Industry Workshops.

Figure 2: Research methodology

RESEARCH FINDINGS: IMPLICATIONS FOR D&B CONTRACTORS

As previously mentioned it has been difficult and in some cases not even possible to separate issues that relate specifically to D&B as an entity of a PPP consortium and issues that relate to the consortium as a whole. For the purposes this paper we have attempted to focus specifically on D&B issues. Our respondents have identified a number of themes, many of which are interrelated. Four dominant themes have been identified and these are discussed in detailed below. They do not encompass all of the issues that we have identified; however, they do provide a framework to describe a major part of our research findings. The themes are as follows:

- tendering/bidding costs;
- legal costs;
- standardization of documentation;
- Public Sector Comparator (PSC)

D&B tendering/bidding costs

One of our basic research questions was 'are tendering costs likely to be higher for a D&B bid in a PPP as opposed to a standard D&B?' Hughes *et al*. (2006) describing a study on the cost of procurement in the construction industry make the statement that there is a 'desperate need for robust data' in respect of tendering costs. While it may appear to be a relatively straightforward matter to identify the costs of bidding for a specific project, in reality this is not the case. To quote from Hughes *et al.*:

> complexity of the data collection places significant hurdles in the way of those who wish to undertake research in this area. This is probably why so few attempts have been made at assessing these costs. The quantification of the costs of tendering that have already been reported in the literature tend to focus on the cost of estimating and bidding, and take no account of the relationship between the distinct stages of a project. Moreover, they are based on impressionistic estimates, rather than analysis of data. However, the fact that they range from 1% to 15% indicates a strong feeling that there is a lot of expenditure in this area, and it is difficult to quantify. Also there is the further conclusion that the value added by this expenditure is not clear.

Hughes *et al.*'s comment on 'impressionistic estimates' is particularly interesting in the context of PPP bidding. We have encountered similar problems in terms of data collection and although we have been able to collect primary data, much of the corroboration of our findings is based on a qualitative rather than a quantitative approach. We certainly empathize with the aptness of Hughes *et al.*'s term 'impressionistic estimating'. In addition to the difficulties associated with accurately allocating costs to a specific tender bid there is the added dimension of the commercially sensitive nature of the data surrounding PPP bidding and also the complex set of commercial relationships that exists within a PPP consortium.

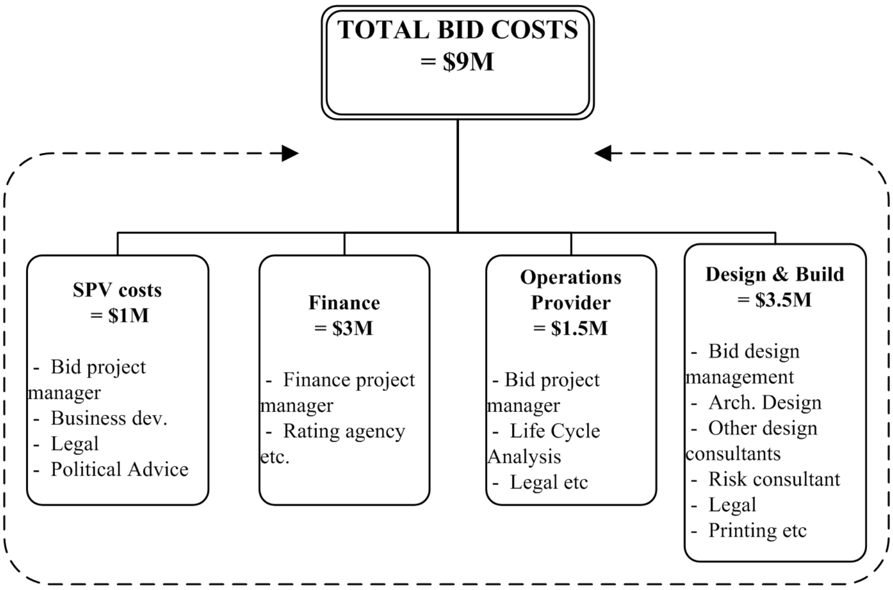


Figure 3: Typical bid costs for $250m PPP social infrastructure project

Note: Bid costs based on the assumption that the bid is successful i.e. to financial closure. If bid is unsuccessful then the financial component, depending on specific circumstances, may be zero.

As can be seen from Figure 3 which illustrates likely (but not actual) bid costs for an AU$250 million social PPP project, the cost of preparing a D&B bid as part of an overall consortium bid cost is likely to exceed one-third of the total cost of bidding. Thus the D&B component is highly significant. We were particularly interested in identifying whether these bid costs would be the same for a standard D&B where the built component was of similar scale and complexity.[3] We have obtained data from our industry collaborators that will allow us to conduct some limited comparative studies and we are in the process of finalizing the collection and analysis of this data. It is not as comprehensive as we had hoped and permission to publish these data still requires clearance by our industry partners.

We have also found that direct comparisons between a ‘standard’ D&B and a D&B as part of a PPP are not as straightforward as might be assumed. There are a number of explanations as to why this might be the case. First, D&B companies may take the view that the utilization of resources in collecting data on the cost of bidding outweighs the benefits. Secondly, whereas external costs (i.e. costs of consultants), are invoiced leaving an accurate paper trail of cost details, internal costs often become absorbed in overheads of the company. D&B companies do not normally operate with very clearly defined cost centres as for example, major accountancy or legal practices, thus the bidding costs of a D&B/PPP (contraction for D&B as part of a PPP) project may be partly absorbed into company overheads and distributed over other non-PPP projects. Further complexities arise in terms of internal relationships within the PPP. For example, D&B contractors may be owned by a larger holding company that may, in turn, be financing the SPV. In this set of circumstances it is likely that that D&B company will automatically be part of the PPP consortium, and will not have to compete to be chosen to be a consortium member. While this would not necessarily affect actual bidding costs it may create cost allocation ‘adjustments’ that would not exist in a standard D&B. On other occasions the SPV may ‘cherry pick’ the D&B contractor from a number of competitors based on criteria determined by the SPV.

An emerging trend in Australia is for construction companies to move away from the provision of equity to the consortium and operate solely as a D&B contractor within the SPV, usually in an attempt to minimize their costs (and risks). However, some financial institutions may insist that contractors provide some upfront equity as a sign of goodwill and a commitment for the duration of the project. Notwithstanding this shift away from providing equity in the consortium, bidding costs for a D&B/PPP are seen as being high and a deterrent to bidding for projects. As a counterpoint there is also the view that bidding in the highly competitive PPP environment could potentially lead to a refinement and sharpening of the bidding process and thus lead to a reduction in the costs of bidding. However, this is likely to be a costly way to gain experience particularly when bids are not successful. In Australia the PPP process has already reduced the pool of bidders. Already fewer competitors function in the market, leading to a reduction in competition, ironically one of the benefits often cited for PPPs. Indeed there would seem to be a general rule of thumb that major PPP players would not be prepared to enter the bidding process where more than three bidders were invited.

In summary we have found the general view to be that the bidding costs for D&B/PPP are higher than for a standard D&B. The basic rationale is that most contractors know what to expect with the standard D&B procurement process, and legal costs are kept to a minimum through the utilization of standardized contract documents. Generally the standard D&B contract process is more predictable, having greater clarity regarding roles and timeframe (the bid period is usually shorter than for a PPP) thus minimizing bid preparation costs. In essence in Australia where standard D&B (or in Australian terminology Design and Construct) has widespread acceptance the fact that it is an established system allows bid preparation costs to be kept to a minimum. By implication, the perceived higher costs of PPP bids are, in part, due to this being a less well-established system with non-standard contracts.

It has been suggested to us that the additional costs could be up to 5–10% higher for a D&B/PPP as opposed to a standard D&B, due, among other things, to the additional legal costs of a PPP bid. Another reason for additional bid preparation costs can occur in the design content where a commercial decision by the consortium to gain a competitive edge could result in higher design costs given that the more developed a design is the more likely it is to be short-listed. Thus, in some cases the design component in a D&B/PPP bid may be more highly developed than for a standard D&B. The expectation for PPP bids is that the submission should have well-developed design documentation. As a corollary to this, the cost of printing is also high with an example provided where the cost of printing contract documentation for a social PPP project valued at AU$300 000 000 was in the region of AU$100 000.

Legal costs

The research described in this paper is primarily concerned with the implications for D&B/PPP contractors when bidding as part of a PPP consortium. Reportage of industry expert opinion on legal costs is therefore focused on legal costs as they relate to D&B. However, it is worth noting that legal costs across the board, i.e. all of the consortium entities, emerged as a dominant theme during our interviews and workshops with industry. The general view was that legal costs are excessively high (although we have not interviewed members of the legal profession to verify this statement). One of the core reasons for the high legal costs cited was lack of standardization of contract documentation. It was acknowledged that legal costs involved in the procurement of infrastructure whether it is a D&B/PPP or a standard

D&B contract were an inevitable corollary of the highly litigious environment in which construction operates. However the general impression given was that legal costs for PPPs were substantially higher than traditional government procurement. It was felt that these costs were a deterrent to some potential bidders. Despite the dissatisfaction expressed regarding high costs, legal costs and associated costs of expert advice, there was general acceptance that this was an integral part of risk mitigation. Furthermore as legal costs are often regarded as non-value added there is perhaps the argument that the issue of legal costs tends to be exaggerated by the construction industry. This is perhaps exacerbated by the fact that social PPP projects tend to be for smaller contract sums and hence attract proportionally higher legal costs. Figure 2 illustrates that legal costs are incurred in all four major entities (SPV; finance; FM provider and D&B) of a PPP bid. Data still being analysed will give us a more precise picture of the legal cost distribution and its ratio to overall bid preparation costs.

The obvious concern of the respondents with legal costs reflects concerns expressed by Evans and Bowman who point out that the legal framework in which the PPP project operates will be a crucial factor to the success of a PPP model: ‘the legal framework within which a PPP project operates will also be a determinant of the optimal PPP model. PPPs will be subjected to legal issues that may encompass many facets of law including (among others) commercial, taxation, insurance, environmental, property, industrial relations and constitutional law’ (2005: 63).

Standardization of legal documents

The consensus view[4] was that there was a lack of consistent principles and practices across the various state jurisdictions in terms of guidelines. Generally it was felt that this lack of consistency increases costs. In an Australian context the Fitzgerald Report (Fitzgerald 2004) recommended that the PPP processes should be streamlined in order to reduce the costs of tenders and encourage wider bidder participation, therefore increasing the competition. It is worth noting that the Public Accounts and Estimates Committee *Report on private investment in public infrastructure* comments that the ‘PPP concept is evolving in different ways in each country’ (2006: 81). There were divergent views on how best to standardize the processes and which model to follow. There was a general concern that international precedents may not reflect the smaller scale of the Australian PPP market. However, the UK PPP model, in which legal/contractual documents have been standardized, is viewed as a reference point for those who recommend standardizing documentation for Australian PPP models. There was general consensus that a reduction in transaction costs could result from standardized templates such as those in the UK. It is worth noting however that despite the introduction of templates in the UK the transaction costs are ‘high and appear likely to remain relatively so despite the development of templates’ (Public Accounts and Estimates Committee 2006: 84).

There was a certain amount of doubt as to whether or not standardization would result in a reduction of legal costs. There was also concern that the process of implementing standardization carried its own costs, requiring a large enough PPP market to justify the initial expenditure.[5]

Public sector comparator

The public sector comparator (PSC) affects all the consortium entities i.e. D&B, FM provider, finance and the SPV, not simply the D&B entity. The PSC purports to provide a benchmark for the complete project life cycle and although the cost to design and build is only one part of the project life cycle it is plays an important part in determining whether the bid is won or lost. It is worth remembering that while the PSC refers to the bid price it may have some influence on the cost of bidding. For example, as previously discussed, there may be commercial pressure to develop designs fully in order to improve the chances of winning the bid and also improve accuracy of costing.

We received a wide-ranging set of views in relation to the value and effectiveness of the public sector comparator (PSC). On the one hand the PSC was seen as a beneficial tool to guide decisions and ensure government accountability; while on the other hand the PSC is often seen as arbitrary and subjective, and consequently of limited value. A commonly held view was that PSC criteria could be manipulated to produce a result that cast the public sector client in a favourable light. These comments are indicative of the current debate both nationally and internationally by commentators and industry representatives regarding the usefulness and accuracy of the PSC (Broadbent *et al*. 2003; Fitzgerald 2004; Corner 2005; Grimsey and Lewis 2005; Public Accounts and Estimates Committee 2006). Critical literature regarding the PSC has incorporated discussion over a variety of issues that have included the appropriate use of the discount rate (English and Guthrie 2003), the failure to take into account risk of failure in the PSC (English 2005: 297) and issues surrounding the public release of the PSC (Grimsey and Lewis 2005: 359).

There would appear to be some disquiet at the differences between Australia's various jurisdictions in relation to the PSC. There was agreement that there should be more consistency in how the PSC is formulated, used and disclosed. PSC polices across the jurisdictions differ in its use and release, ranging from total secrecy to an open general policy of release. Some jurisdictions, such as the Commonwealth and South Australia, do not have a general rule on releasing the PSC. In contrast Victoria, Tasmania and the Australian Capital Territory do have a general rule against full disclosure of the PSC and in Western Australia until the contract is executed the PSC remains confidential (Public Accounts and Estimates Committee 2006: 84).

The failure of some jurisdictions to fully disclose the PSC was particularly criticized by respondents, stating that it was unnecessary for it to remain confidential. Many believed that the process of withholding the PSC was counterproductive, that it increased bidding costs and it would be more beneficial for a project outcome that the PSC was open for general comment. Many were cynical that without disclosing the PSC government would not have to justify how the final PSC costing was derived.

However, a shift towards partial disclosure of the PSC in States that currently withhold the information is evident with the recent recommendations made in February 2006 by the Victorian Department of Treasury and Finance to present the public service comparator early in the bid phase in an effort to reduce bidding costs. Nevertheless the Department of Treasury & Finance has since further qualified the status of this recommendation stating … 'the aim of the presentation is not to disclose the detailed costing of the PSC, rather to further clarify the governments expectations' (Public Accounts and Estimates Committee 2006: 76).

There was some frustration regarding the practice of government authorities withholding of the PSC during the negotiation stage. Bidders are measured against this comparator, but have no insight into the PSC and hence are effectively bidding 'blind'. There were also some concerns expressed that the PSC unduly influenced the size and scope of projects, and whether or not a project proceeded. Criticism in current literature supports this notion that the PSC can be used incorrectly as a pass/fail test despite the 'many uncertainties involved in the calculation and the fact that the numbers could have been manipulated to obtain the desired results' (Bult-Spiering and Dewulf 2006: 100).

CONCLUSIONS

The main thrust of this paper has described what, in our view, is a reasoned distillation of opinions by major industry D&B/PPP contractors on some of the implications of bidding for and undertaking D&B/PPP contracts in the current Australian market. The overall impression presented in this paper may have been one of negativity; however, this is perhaps a reflection on the embryonic nature of the social PPP market in Australia where lack of consistency between the various State governments appears to be a problem specific to Australia. There would seem to be little doubt that a D&B/PPP as opposed to a standard D&B creates additional pressures. These pressures (at least for the larger players) are magnified on social as opposed to economic PPPs where the projects on offer are potentially less lucrative than economic PPPs and where the bid–cost ratio is higher.

The PPP market in Australia, particularly for social PPPs, is gathering momentum but is less mature than that of the UK. The rate of maturation may be inhibited, to some extent, by the scale of the available market (in comparison to the UK) and the compartmentalization of the market on a State-by-State basis. However, as previously discussed, there are moves towards the standardization of documentation (particularly by the Victorian Government) and the existence of a National PPP Forum is encouraging (see http://www.pppforum.gov.au/home).

Fundamentally the challenges to D&B/PPP contractors result from having to interact with a large number of players in a dynamic environment where the SPV and not the D&B contractor are in the dominant position. Throughout this paper the term 'complex' has been frequently used to describe the interrelationship of players in a PPP consortium. Certainly the consortium environment seems to mimic some of the characteristics described in complex systems theory such as 'non-linearity' where systems do unpredictable things and 'emergent properties' where a logical result is achieved, although not necessarily a predictable one. There are reservations among industry players about the efficacy of the PPP approach and some would perhaps prefer to operate in the much more controlled relationship that exists under a standard D&B procurement method. However, notwithstanding any reservations that may exist on PPPs, there is general acceptance that social PPPs are part of the procurement landscape in Australia and likely to remain so for the foreseeable future.

NOTES

[1] The working definition of PPPs for this research is based on that of Akintoye *et al*. (2003): 'a long-term contractual arrangement between a public sector agency and a private sector concern, whereby resources and risk are shared for the purpose of developing a public facility'.

[2] Argy *et al.* (1999, cited in Grimsey and Lewis 2004: 20–1) make the following useful distinctions between types of PPPs:

- hard economic infrastructure e.g. roads;
- soft economic infrastructure e.g. financial institutions;
- hard social infrastructure e.g. hospitals;
- soft social infrastructure e.g. social security.

[3] Since commencing our research Fitzgerald and Duffield (2006) have announced a National Benchmarking Study comparing PPP projects versus more standard procurement strategies. The study focuses on the bid price, not the cost of bidding.
[4] These comments are specific to Australia with its federal system of government as opposed to the Westminster system.
[5] Since the initiation of the research project various government agencies have begun to standardize some of their processes based upon previous lessons learnt or criticism from the private sector. Respondents commented that all levels of government appear to be committed to refining contractual negotiations, in order to reduce extended legal debates which are costly not only for the contractors involved but also for government.

REFERENCES

Akintoye, A, Beck, M and Hardcastle, C (2003) *Public–private partnerships: managing risks and opportunities*. Oxford: Blackwell Science Ltd.

Argy, F, Lindfield, M, Stimson, B and Hollingsworth, P (1999) Infrastructure and economic development. *CEDA Information Paper No. 60.* Melbourne, Committee for Economic Development of Australia.

Blood, G (2005) Australian PPPs, the third way. *Infranews Wire.*

Broadbent, J, Gill, J and Laughlin, R (2003) The private finance initiative in the UK: contracting in the context of infrastructure investment and control. *International Public Management Journal*, **6**, 173–97.

Bult-Spiering, M and Dewulf, G (2006) *Strategic issues in public–private partnerships: an international perspective.* Oxford: Blackwell Publishing Ltd.

Corner, D (2005) The United Kingdom private finance initiative: the challenge of allocating risk. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

Curnow, W, Jefferies, M C and Chen, S E (2005) Unsustainable bidding costs – a critical issue for public private partnerships. *In*: W Curnow, M C Jefferies and S E Chen (Eds.) *The Hong Kong Institution of Engineers Conference Public Private Partnerships – Opportunities and Challenges*, 22 February. Hong Kong Creative Consulting Group, 35–43.

Duffield, C F (2005) PPPs in Australia. *In:* C F Duffield (Ed.) *Public private partnership – opportunities and challenges*. Hong Kong.

English, L (2005) Using public–private partnerships to deliver social infrastructure: the Australian experience. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

English, L M and Guthrie, J (2003) Driving privately financed projects in Australia: what makes them tick? *Accounting, Auditing & Accountability Journal*, **16**, 493–502.

Evans, J and Bowman, D (2005) Getting the contract right. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

Fitzgerald, J and Duffield, C F (2006) The performance of major Australian projects: A comparison of PPP projects versus more traditional procurement strategies. *In*: J Fitzgerald and C F Duffield (Eds.) *1st International Construction Specialty conference, Canadian Society for Civil Engineering*, 23–26 May, Calgary, Canada.

Fitzgerald, P (2004) *Review of partnerships Victoria*, Final Report to the Treasurer, Department of Treasury and Finance, State Government of Victoria. Melbourne: Growth Solutions Group.

Grimsey, D and Lewis, M K (2004) *Public private partnerships, the worldwide revolution in infrastructure provision and project finance.* Cheltenham: Edward Elgar Publishing Limited.

Grimsey, D and Lewis, M K (2005) Are public private partnerships value for money? Evaluating alternative approaches and comparing academic and practioner views. *Accounting Forum*, **29**, 345–78.

Hughes, W P, Hillebrandt, P, Greenwood, D G and Kwawu, W E K (2006) *Procurement in the construction industry: the impact and cost of alternative market and supply processes.* London: Taylor & Francis.

Jones, D (2003) Evaluating what is new in the PPP pipeline. *Building and Construction Law*, **19**, 250–70.

Public Accounts and Estimates Committee (2006) *Report on private investment in public infrastructure*, Parliament of Victoria, State Government of Victoria. No. 240, Session 2003–06. Melbourne: Government Printer.

[3] Since commencing our research Fitzgerald and Duffield (2006) have announced a National Benchmarking Study comparing PPP projects versus more standard procurement strategies. The study focuses on the bid price, not the cost of bidding.
[4] These comments are specific to Australia with its federal system of government as opposed to the Westminster system.
[5] Since the initiation of the research project various government agencies have begun to standardize some of their processes based upon previous lessons learnt or criticism from the private sector. Respondents commented that all levels of government appear to be committed to refining contractual negotiations, in order to reduce extended legal debates which are costly not only for the contractors involved but also for government.

REFERENCES

Akintoye, A, Beck, M and Hardcastle, C (2003) *Public–private partnerships: managing risks and opportunities*. Oxford: Blackwell Science Ltd.

Argy, F, Lindfield, M, Stimson, B and Hollingsworth, P (1999) Infrastructure and economic development. *CEDA Information Paper No. 60.* Melbourne, Committee for Economic Development of Australia.

Blood, G (2005) Australian PPPs, the third way. *Infranews Wire.*

Broadbent, J, Gill, J and Laughlin, R (2003) The private finance initiative in the UK: contracting in the context of infrastructure investment and control. *International Public Management Journal*, **6**, 173–97.

Bult-Spiering, M and Dewulf, G (2006) *Strategic issues in public–private partnerships: an international perspective.* Oxford: Blackwell Publishing Ltd.

Corner, D (2005) The United Kingdom private finance initiative: the challenge of allocating risk. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

Curnow, W, Jefferies, M C and Chen, S E (2005) Unsustainable bidding costs – a critical issue for public private partnerships. *In*: W Curnow, M C Jefferies and S E Chen (Eds.) *The Hong Kong Institution of Engineers Conference Public Private Partnerships – Opportunities and Challenges*, 22 February. Hong Kong Creative Consulting Group, 35–43.

Duffield, C F (2005) PPPs in Australia. *In:* C F Duffield (Ed.) *Public private partnership – opportunities and challenges*. Hong Kong.

English, L (2005) Using public–private partnerships to deliver social infrastructure: the Australian experience. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

English, L M and Guthrie, J (2003) Driving privately financed projects in Australia: what makes them tick? *Accounting, Auditing & Accountability Journal*, **16**, 493–502.

Evans, J and Bowman, D (2005) Getting the contract right. *In*: G Hodge and C Greve (Eds.) *The challenge of public–private partnerships: learning from international experience.* Cheltenham: Edward Elgar Publishing Limited.

Fitzgerald, J and Duffield, C F (2006) The performance of major Australian projects: A comparison of PPP projects versus more traditional procurement strategies. *In*: J Fitzgerald and C F Duffield (Eds.) *1st International Construction Specialty conference, Canadian Society for Civil Engineering*, 23–26 May, Calgary, Canada.

Fitzgerald, P (2004) *Review of partnerships Victoria*, Final Report to the Treasurer, Department of Treasury and Finance, State Government of Victoria. Melbourne: Growth Solutions Group.

Grimsey, D and Lewis, M K (2004) *Public private partnerships, the worldwide revolution in infrastructure provision and project finance.* Cheltenham: Edward Elgar Publishing Limited.

Grimsey, D and Lewis, M K (2005) Are public private partnerships value for money? Evaluating alternative approaches and comparing academic and practioner views. *Accounting Forum*, **29**, 345–78.

Hughes, W P, Hillebrandt, P, Greenwood, D G and Kwawu, W E K (2006) *Procurement in the construction industry: the impact and cost of alternative market and supply processes.* London: Taylor & Francis.

Jones, D (2003) Evaluating what is new in the PPP pipeline. *Building and Construction Law*, **19**, 250–70.

Public Accounts and Estimates Committee (2006) *Report on private investment in public infrastructure*, Parliament of Victoria, State Government of Victoria. No. 240, Session 2003–06. Melbourne: Government Printer.

BIDDING MODEL FOR DESIGN/BUILD PROJECTS

Li-Chung Chao[1]

Construction Engineering, National Kaohsiung First University of Science and Technology, 1 University Road, Yenchao, Kaohsiung, 824, Taiwan, Republic of China

A contractor in bidding for a design/build (D/B) project needs to submit a technical proposal for design and construction fulfilling the project brief, along with a price proposal. The owner will compare each bidder's value versus price in determining the 'best value for money' for contract award. Hence, a contractor's bid price decision for a D/B project should reflect not only the cost but also the relative value of the firm's service, making the decision more complex than for a construction-only project. It would be difficult to determine the optimum bid price by using experience and intuition alone. This paper presents a research that focuses on how much mark-up a contractor should apply on top of the estimated cost for a D/B project. It is proposed that the relative value of service is self-assessed using the analytical hierarchy process and according to the owner's evaluation criteria. The probability of winning for a bid is estimated with considerations of the owner's tender evaluation and the competition in the target market. The mark-up that achieves the maximum expected profit after reducing the allowance for project risk is recommended for bid price decision. The proposed model is illustrated using a case project in response to a commonly used approach for contractor selection.

Keywords: bidding, design and build, estimating, pricing, risk analysis.

INTRODUCTION

The design/build (D/B) method of procurement has now been widely adopted by public and private owners in many countries for a variety of construction projects. As a result, D/B projects have become an important source of business for contractors in the construction industry. When the owner uses the D/B method to procure a project, the contractor selection procedure normally requires a bidder to submit a technical proposal for design and construction fulfilling the project brief, along with a price proposal, for the owner's evaluation. Since there are differences in qualifications, experience and technical proposals among the bidders, representing different values, the owner in evaluation of tenders will compare each bidder's value versus the price asked in order to determine the 'best value for money' for contract award, which is unlike awarding a construction-only contract normally to the lowest bid.

While contractor selection for a D/B project becomes more complex and difficult for the owner, preparation of the required proposals and making the bid price decision are more demanding for the contractor. As a response to the owner's evaluation method, a D/B contractor's bid price decision should reflect not only the cost of the project but also the relative value of the firm's service, considering factors that are not present in bidding for construction-only projects. Although the competitors are fewer and the

[1] chaolc@ccms.nkfust.edu.tw

profit margin is likely to be higher as a result of the owner's use of prequalification for screening bidders and the high cost of bid preparation, the bid price of a hopeful contractor still needs to be competitive because only one will win the contract. In addition, because the design is not fully completed at the time of bidding, there are more uncertainties in the cost estimate, while an enlarged scope of contract entails more interfaces and design- and site-related problems to be self-handled, meaning a higher risk for the contractor. These are the reasons why bid price decision for a D/B project is more challenging than for a construction-only project and it is fair to say that considerations for the latter are a subset of those for the former.

The focus of the research reported below is on how much mark-up a contractor should apply in determination of the bid price for a D/B project when the firm has made a cost estimate based on its produced outline design deemed most appropriate for the project. It is difficult to achieve an optimum bid price decision under the complexities mentioned above by using experience and intuition alone. It would be helpful to apply quantitative analysis methods to dealing with the problem. Thus, the purpose of the research is to develop an objective-function-based model for determining the optimum mark-up for a D/B project. The results of a pilot study are presented in this paper.

BACKGROUND STUDY

Because of its importance in construction, the bidding problem has long attracted much research interest and many prescriptive bidding models can be found in the literature. However, few of them are oriented particularly towards the circumstances of D/B projects. For example, based on awarding a contract to the lowest bid, the probability model in Carr (1982) uses statistics of historical bid data for estimating the probability of winning for a given mark-up. The optimum mark-up is determined as the one with the maximum expected profit, where the expected profit for a mark-up is defined as the product of the probability of winning multiplied by the mark-up. Farid and Boyer (1985) proposed a present value model based on a contractor's cash flows analysis for a project and required rate of return to determine the minimum acceptable mark-up for bid price decision. These early models can be termed as academic since they do not include the various subjective and qualitative factors that contractors consider in making the bid decision.

Researches in recent years have turned towards developing models using multiple factors as inputs to reflect the many facets of the mark-up problem. For example, Dozzi *et al*. (1996) used 21 factors identified by Ahmad and Minkarah (1988) and grouped under environment, company and project as the criteria in a multi-attribute utility model. The utility of a project is obtained from the assessments of the factors that are translated by utility functions into utility measurements and the recommended mark-up is derived from the inverse relation between project utility and required mark-up. The neural network model by Moselhi *et al*. (1993) and the fuzzy neural network model by Liu and Ling (2005) are trained with collected data representing a number of bidding situations and the corresponding mark-ups to be applied. Chua and Li (2000) listed 51 factors and evaluated their effects based on a survey, based on which Chua *et al*. (2001) proposed a case-based reasoning model using the identified factors as case attributes. Though these multi-factor models offer various methods for obtaining an optimum mark-up, they do not particularly address D/B projects either.

Mochtar and Arditi (2001) investigated the role of marketing information in bid price decision and proposed pricing strategies using market-based approaches centred on marketing intelligence systems. However, even if there is enough information on market prices collected through efficient marketing systems, making the bid price decision still requires considering the uniqueness and complexities of an individual project. Although the cost estimate would still be the basis of a bid price, the nature of design and build procurement gives more room for product differentiation and hence allows it to be closer to value-based pricing, which is commonly used for products and services in other industries.

MODEL DESCRIPTION

The research requires an understanding of owners' methods for tender evaluation for D/B projects. Palaneeswaran and Kumaraswamy (2000) presented the findings of an investigation of the criteria and practices used by owners in many countries and listed a collection of formulas for combining the technical and price scores. It is obvious that the method used by the owner for tender evaluation influences the way of estimating the chance of winning for a given bid price for a D/B project and hence needs to be considered in the proposed bidding model. In addition, the previously mentioned considerations in bidding for a D/B project, i.e. service value, competition, and project risk, need to be addressed as well, as discussed in the following.

On the premise that profit represents a contractor's global goal in bidding for a project, the bid decision is to maximize the following objective function.

$$EV = P_w \times (r - \bar{c} / c) \qquad (1)$$

where EV = expected profit ratio; P_w = probability of winning; r = bid/cost ratio; $\bar{c}$ = mean project cost; c = estimated project cost.

In Equation 1, r is the decision variable and a bid b is simply the product of r multiplied by c, which includes all required direct costs and site and company overheads. The percentage mark-up of b is $(b – c)/c$ or $r – 1$. The optimum bid corresponds to the r achieving the highest EV. While P_w is a function of r, estimating P_w for a given r will have to take into account the firm's service value and the competition faced. The firm's service value is to be self-assessed within the framework of multi-dimensional analysis. The competition faced is influenced by current economic and market conditions as reflected by the statistics of recent winning bids for similar projects in the target market representing the prevailing bid level. The component of $\bar{c} / c$ relates to project risk and $r - \bar{c} / c$ represents the profit ratio after deducting the allowance for project risk, given that the firm wins the bid. More details on the above are given below.

A bidder's relative service value compared to a competitor can be assessed using the AHP (analytical hierarchy process) method, which is more convenient than the utility theory and has been applied to problems of multi-attribute evaluation in many fields, e.g. evaluation of advanced construction technology (Skibniewski and Chao 1992). Self-assessment using the AHP method is shown in an example here.

Assume that a contractor (the firm) is bidding for a building D/B project, for which the owner's evaluation criteria are: planning and land use (30%), quality of design and construction (40%), maintainability and serviceability (20%), and company's track records (10%). If the firm considers its offered planning and land use slightly better than that of a typical competitor in the target market, then, on a scale of 1 to 9 where 1 indicates parity and 9 indicates absolute superiority, a value of 2 is entered in the comparison matrix in Table 1, producing a principal eigenvector of [0.67, 0.33] as the result of assessment for this criterion. For the other three criteria, the comparison matrices and principal eigenvectors produced are shown in Tables 2 to 4.

Table 1: Self-assessment on planning and land use

Alternatives	Firm	Typical competitor A*
Firm	1	2
Typical competitor A*	1/2	1
Principal eigenvector	0.67	0.33

Table 2: Self-assessment on quality of design and construction

Alternatives	Firm	Typical competitor A*
Firm	1	1/2
Typical competitor A*	2	1
Principal eigenvector	0.33	0.67

Table 3: Self-assessment on maintainability and serviceability

Alternatives	Firm	Typical competitor A*
Firm	1	3
Typical competitor A*	1/3	1
Principal eigenvector	0.75	0.25

Table 4: Self-assessment on company's track records

Alternatives	Firm	Typical competitor A*
Firm	1	1/5
Typical competitor A*	5	1
Principal eigenvector	0.2	0.8

Aggregation of the comparison results in eigenvectors and the weight vector for the owner's evaluation criteria is accomplished by means of matrix multiplication as shown below, to obtain a self-assessment of the firm's service.

$$\begin{bmatrix} 0.67 & 0.33 & 0.75 & 0.20 \\ 0.33 & 0.67 & 0.25 & 0.80 \end{bmatrix} \times \begin{bmatrix} 0.30 \\ 0.40 \\ 0.20 \\ 0.10 \end{bmatrix} = \begin{bmatrix} 0.503 \\ 0.497 \end{bmatrix} \tag{2}$$

If a typical competitor's technical score is normalized as unity, then the firm's self-assessment of service for the D/B project can be reduced to v = 0.503/0.497 = 1.012, slightly better than the norm.

The competition faced for the project can be assessed by referring to the ratios of winning bid to estimated cost for recent similar projects in the same market. The lower the ratios are, the keener the likely competition would be, and the lower the chance of winning for a bid price will be. Together with the obtained self-assessment of the technical proposal and statistics of winning bids, the way of the owner's tender evaluation and the weight given to the price proposal will influence the assessment of the chance of winning for a given bid. A case of tender evaluation is given later to illustrate the quantification of the relation between P_w and r.

In Equation 1, c, the firm's estimated project cost, is produced by aggregating the most likely cost estimates for all items of work, whereas $\bar{c}$, the mean project cost, is obtained from the probability distribution for project cost using a probabilistic cost-estimating technique as an extension of the traditional deterministic estimation.

Because of the existence of many uncertainties in a D/B project relating to productivity, resource prices, design interfaces, etc., the distribution for item cost is usually skewed positively to the right, i.e. the mean cost for an item tends to be higher than the mode. As a result, $\bar{c}$ is usually greater than *c*, i.e. $\bar{c}/c > 1$, which is evidenced by the actual project cost often higher than the estimated project cost. The difference between $\bar{c}$ and *c* is the allowance for project risk in the bid mark-up, hence deducting the risk allowance from the mark-up gives the net profit in a bid, i.e. $b - c - (\bar{c} - c) = b - \bar{c}$ or, as a percentage of *c*, $(b - \bar{c})/c = r - \bar{c}/c$.

ILLUSTRATIVE CASE

The proposed bidding model is illustrated using a case of tender evaluation. The case is the common practice of public sector owners awarding a D/B contract to the lowest adjusted bid, where an adjusted bid, *b'*, is the bid price divided by the technical score, i.e. *b' = b/v*. Assume that for the example building project above the firm produces a cost estimate of *c* = \$35 220 000 based on its outline design. Addressing the various risks involved in the project, the firm obtains a probability distribution for project cost with $\bar{c}$ = \$35 684 000 and $\bar{c}/c$ =1.0132. Now the question is how much mark-up, or equivalently, what bid/cost ratio, should be applied in the bid price decision.

This case of tender evaluation is a variant of the traditional method of awarding a contract to the lowest bid normally used for construction-only jobs. However, because the bids received for a project that uses the traditional contract award method can be considered as having the same service value of *v* = 1, bid data for construction-only contracts, of which there are plenty, can still be referred to in estimating the probability of winning for a bid in the case. Meanwhile, the existing methods of estimation based on the statistics of bid/cost ratios should be adapted to fit the condition of contract award to the lowest adjusted bid that requires considering the effect of the technical score represented by *v*. For example, if for similar projects in the same market the ratio of the lowest opposing bid to the firm's estimated cost is found to be normally distributed with a mean of 1.03 and a standard deviation of 0.04, then with *v* = 1.012 the P_w for a given bid/cost ratio *r* is assessed as:

$$P_w = \int_{r/v}^{\infty} N(\mu, \sigma^2)dy = \int_{r/1.012}^{\infty} N(1.03, 0.04^2)dy \qquad (3)$$

where *N* refers to the normal distribution.

Table 5 shows the obtained probabilities of winning for various bid/cost ratios and the corresponding expected profit ratios from Equation 1. The maximum expected profit ratio is achieved at *r* = 1.055, thus the recommended bid price for the project according to the model is 1.055 × \$35 220 000 = \$37 157 100.

Table 5: Evaluation results for case project

Bid/cost ratio, *r*	Adjusted bid/cost ratio, *r/v*	Probability of winning, Pw	Expected profit ratio, EV
1.035	1.023	0.572	0.0125
1.040	1.028	0.523	0.0140
1.045	1.033	0.474	0.0151
1.050	1.038	0.425	0.0157
1.055	1.042	0.377	0.0158
1.060	1.047	0.332	0.0155
1.065	1.052	0.288	0.0149
1.070	1.057	0.247	0.0141
1.075	1.062	0.210	0.0130

CONCLUSIONS

Bidding for a D/B project has to respond to the owner's contractor selection method. The factors involved in pricing can be summarized in three main points, i.e. service value, competition and project risk, based on which a bidding model is proposed that maximizes an objective function measuring the expected profit of a bid. The critical part is estimating the probability of winning for a given mark-up level, for which the method will vary according to the owner's tender evaluation. Although the presented case of contract award to the lowest adjusted bid can be dealt with easily by using a modification of the existing estimating method, there are other formulas for tender evaluation that are more complex. Studies are currently underway in response to owners using different tender evaluations. In the future, the optimum bid determined by such models needs to be verified using real data. Currently, real D/B case projects are being collected for the purposes of testing and possible adaptation of the proposed model, i.e. an objective function for determining the optimum bid mark-up and the accompanying method for estimating the probability of winning for a given bid mark-up, and the results will be reported in a subsequent paper. It is hoped that with the assistance of a bidding model the more challenging bid decision for a D/B project can be made in a rational way to cope with the expanding D/B markets.

REFERENCES

Carr, R I (1982) General bidding model. *ASCE Journal of Construction Division*, **108**(CO4), 639–50.

Chua, D K and Li, D (2000) Key factors in bid reasoning model. *ASCE Journal of Construction Engineering and Management*, **126**(5), 349–57.

Chua, D K H, Li, D Z and Chan, W T (2001) Case-based reasoning approach in bid decision making. *ASCE Journal of Construction Engineering and Management*, **127**(1), 35–45.

Dozzi, S P, AbouRizk, S M and Schroeder, S L (1996) Utility-theory model for bid markup decisions. *ASCE Journal of Construction Engineering and Management*, **122**(2), 119–24.

Farid, F and Boyer, L T (1985) Pricing model. *ASCE Journal of Construction Engineering and Management*, **111**(4), 374–89.

Liu, M and Ling, Y Y (2005) Modeling a contractor's markup estimation. *ASCE Journal of Construction Engineering and Management*, **131**(4), 391–9.

Mochtar, K and Arditi, D (2001) Role of marketing intelligence in making pricing policy in construction. *ASCE Journal of Management in Engineering*, **17**(3), 140–8.

Moselhi, O, Hegazy, T and Fazio, P (1993) DBID: analogy-based DSS for bidding in construction. *ASCE Journal of Construction Engineering and Management*, **119**(3), 466–79.

Palaneeswaran, E and Kumaraswamy, M (2000) Contractor selection for design/build projects. *ASCE Journal of Construction Engineering and Management*, **126**(5), 331–9.

Skibniewski, M J and Chao, L-C (1992) Evaluation of advanced construction technology with AHP method. *ASCE Journal of Construction Engineering and Management*, **118**(3), 577–93.

A SYSTEM REVIEW OF COMPETITIVE BIDDING AND QUALIFICATION-BASED SELECTION SYSTEMS

Wei Lo[1] and Min-Ren Yan[2]

[1]*Department of Construction Engineering, National Kaohsiung First University of Science and Technology, No.2, Jhuoyue Rd, Nanzih District, Kaohsiung City 811, Taiwan*
[2]*Institute of Engineering Science and Technology, National Kaohsiung First University of Science and Technology, No.2, Jhuoyue Rd, Nanzih District, Kaohsiung City 811, Taiwan*

The competitive bidding system and qualification-based selection (QBS) system are two mainstreams of contractor selection today. However, most of the discussions relating to these two systems have concerned the project level viewpoint and little attention has been drawn to the long-range impacts of the contractor selection systems on contractors' competitive behaviour or on the whole construction industry from a holistic and system perspective. This paper broadly adopts the findings of previous research and explicitly depicts the causal relationships between different contractor selection systems and contractors' competitive behaviours to demonstrate (a) how a competitive bidding system generates economic benefit and encourages contractors to improve their capabilities; (b) how a competitive bidding system encourages contractors' opportunistic bidding behaviour which forms adverse cycles and hinders the development of the construction industry; and (c) how a QBS system can reduce the opportunistically abnormal low bids and lead contractors' competitive behaviour into positive paths. Several strategies including improving the construction management system, increasing the use of non-price criteria, and implementing prompt contractor performance rating systems are proposed to promote the project success.

Keywords: bidding, contracting, procurement, systems analysis, tendering.

INTRODUCTION

The contractor selection system is always the most important issue for the client in implementing a construction project. For decades, competitive bidding has been extensively used for almost all kinds of procurement worldwide. Governments utilize competitive bidding for its simplicity and fairness and expect to obtain economic benefit through price competition. However, abnormal low bids and consequently poor project quality have frequently occurred. The qualification-based selection (QBS) system has been considered as an alternative way to find competent contractors. However, most of these studies have concerned the project level viewpoint. To fill this gap, this study aims to analyse the long-range impacts caused by the change of contractor selection systems on contractors' competitive behaviour as well as on the whole construction industry from a holistic and system perspective.

[1] roylo@ccms.nkfust.edu.tw

SYSTEMS THINKING AND THE CAUSAL-LOOP DIAGRAM

Systems thinking has its foundation in the field of system dynamics, founded in 1956 by MIT professor Jay Forrester. The approach of systems thinking is fundamentally different from that of traditional forms of analysis. Traditional analysis focuses on separating the individual pieces of what is being studied. In contrast, systems thinking focuses on how the thing being studied interacts with the other constituents of the system. A causal loop diagram is a kind of systems thinking tool. The diagram aids in visualizing how interrelated variables affect one another. Complicated and correlated variables are integrated into a loop relationship, called a ‘feedback loop’. The feedback loops can be divided into two categories based on their effects: (a) the ‘reinforcing feedback loop’ which shows the effects of malign or benign cycles; (b) the ‘balancing feedback loop’ which symbolizes the tendency to maintain a goal.

REVIEW OF COMPETITIVE BIDDING SYSTEM

This section theoretically reviews the previous research and depicts the behaviour feedback loops generated from the use of the competitive bidding system. The feedback loops are classified into three groups: (a) the feedback loops generated from the price competition process; (b) the feedback loops generated from contractors’ cost reduction; and (c) the adverse feedback loops generated from contractors’ opportunistic bidding behaviour.

The feedback loops generated from the price competition process

There are two feedback loops generated from the process of price competition. One is a reinforcing feedback loop and another one is a balancing feedback loop as follows:

The reinforcing feedback loop, R1

The Bertrand competition model of economics proposed that, in a price competition environment, companies will assess and predict prices that their competitors may offer before they determine their own price (Carlton and Perloff 2000). Accordingly, the bidding prices of previous tenders (hereafter termed market price) are important references for bidders of subsequent tenders and have feedback relationships with contractors’ bidding prices as shown in Figure 1. The market price is an index changing with the recent award prices. The previous bidding prices sequentially affect contractors’ pricing in the subsequent tenders and form a reinforcing feedback loop, which allows project owners to obtain economic benefits, as R1 in Figure 1. The positive sign, ‘+’, indicates that a change in the causal variable (market price) will cause a change in the variable (bidding price) it is affecting in the same direction.

The balancing feedback loop, B1

Runeson and Raftery (1998) applied micro-economic theory to analyse the competitive market in the construction industry and proposed that price determination is based on the interaction of demand and supply. Ngai *et al*. (2002) proposed that the changes in demand and/or supply will change the level of competition and the tender price level. The level of competition is usually observed and measured through the number of competitors.

Previous studies have shown that a contractor’s bidding price will be affected by the number of competitors (Freidman 1956; Carr 1983). As the number of competitors increased, contractors’ bidding price decreased. This opposite relationship is represented by a negative sign, ‘–’, as shown in Figure 1. Furthermore, several studies have suggested that companies will leave or enter a market because of changes in profit level (Gruneberg and Ive 2000; Hillebrandt 2000; Runeson 2000). The findings clearly depict an identical causal relationship between market price and number of competitors.

According to the aforementioned, a balancing feedback loop, B1, is discovered. A higher market price will attract more competitors to join the bidding game, but in the meantime, these competitors need to steeply cut prices to win contracts in a fiercely competitive market. Consequently, the market price might drop down to a lower level and force some competitors to quit the market. This feedback process depicts a company’s behaviour in response to the supply and demand relationship until both the market price and the number of competitors are balanced.

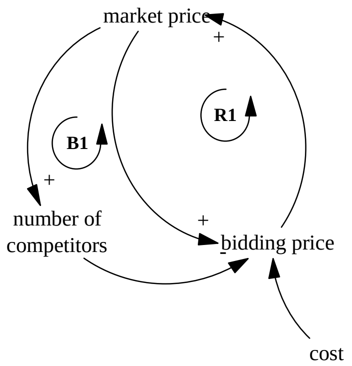


Figure 1: The price competition process

The feedback loops generated from contractors’ cost reductions

This section introduces how the competitive bidding system can encourage contractors to renovate technologies and management skills to reduce costs. Four feedback loops generated from contractors’ cost reductions are discussed as follows:

The reinforcing feedback loops, R2 and R3

Under the price competition system, contractors can win awards by reducing their expected profit and reducing costs. But when competition is intensified to a certain extent, eventually the market price will approach contractors’ costs. Gransberg and Ellicott (1996) proposed that the low-bid method implies that it selects the contractor with the most innovative, cost-effective solution to construct the facility. Thus, contractors have to face issues of innovation and cost reduction, so as to take awards and pursue continuous development. When contractors strive to reduce their costs and expand their market, contractors can have more opportunities to accumulate work experience and to invest in R&D. As a result, their technical and management skills will be improved, so as to reduce bidding prices and their market share will be further increased. Fu *et al.* (2003) have conducted a statistical analysis to corroborate this positive learning effect on contractor’s competitiveness. Two reinforcing feedback loops guiding contractors to continuous development are formed (see loops R2 and R3 in Figure 2).

The balancing feedback loops, B2 and B3

It is recognized that under the competitive bidding system, an owner may award a project to an abnormally low bid, because of cursory cost estimation (Capen *et al.* 1971). This situation can be avoided by improving contractors’ professionalism. From the system perspective, a competent contractor can continuously improve its technical and management skills through R2 and R3 reinforcing loops, so as to reduce the probability of underestimates and form the balancing loops, B2 and B3 (see Figure 3).

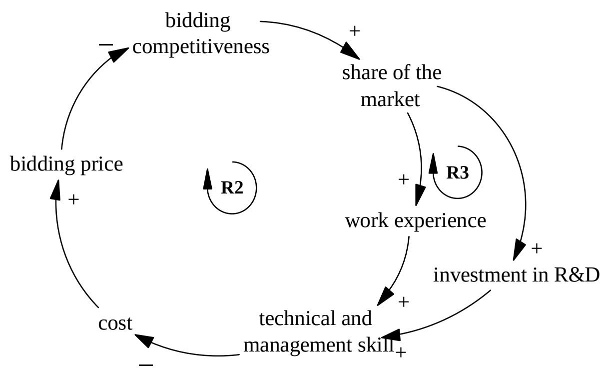


Figure 2: The feedback loops generated as a contractor improves his technical and management skills (a)

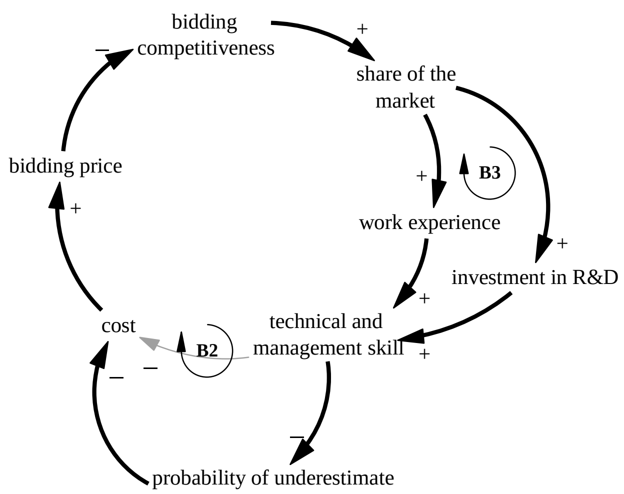


Figure 3: The feedback loops generated as a contractor improves his technical and management skills (b)

The adverse feedback loops

Under the competitive bidding system, contractors may win the bid by tendering an abnormally low bid, accidentally or deliberately (Grogan 1992). Previous studies have suggested that contractors will adopt some strategies to compensate for the deficit, such as cutting corners to lower costs (Winch 2000) and bringing up claims against the owner (Crowley and Hancher 1995a), when they begin the construction with an unfavourable contract price. Doyle and DeStephanis (1990) warned that certain bidders extensively review bid documents, noting mistakes, cataloguing ambiguities, and looking for future change orders or claims. These bidders can lower their bid prices with the knowledge that on subsequent change orders or claims they can recapture monies that were initially sacrificed for the award (Crowley and Hancher 1995b). Ho and Liu (2004) applied game theory to analyse contractors' bidding behaviour and concluded that contractors will lower the bid when they expect profits from claims. Rooke *et al.* (2004) introduced the concept of 'proactive claims' and 'reactive claims' and concluded that claims have been an important source of contractors' profits. Lo *et al.* (2007) considered the cost reductions through cutting corners and the compensations gained from claims as 'beyond-contractual reward' (BCR) and proposed that, when contractors have an expectation to gain BCR, they will opportunistically cut the bid price to take more market share. Based on the aforementioned evidence, six adverse reinforcing feedback loops hidden within the competitive bidding system are discovered as follows:

The reinforcing feedback loops, R4 and R5

Opportunism is one of the most important behavioural assumptions in economic theories. It says that companies always want more of what they like, and this may imply that interests are pursued in an opportunistic fashion (Williamson 1985). Thus, it is reasonable to assume that, when contractors have experienced obtaining BCR in the past, they tend to repeatedly cut corners and raise claims in order to gain the maximum profit, whether the award price is reasonable or not. The reinforcing feedback loops, R4 and R5, are thus formed as shown in Figure 4.

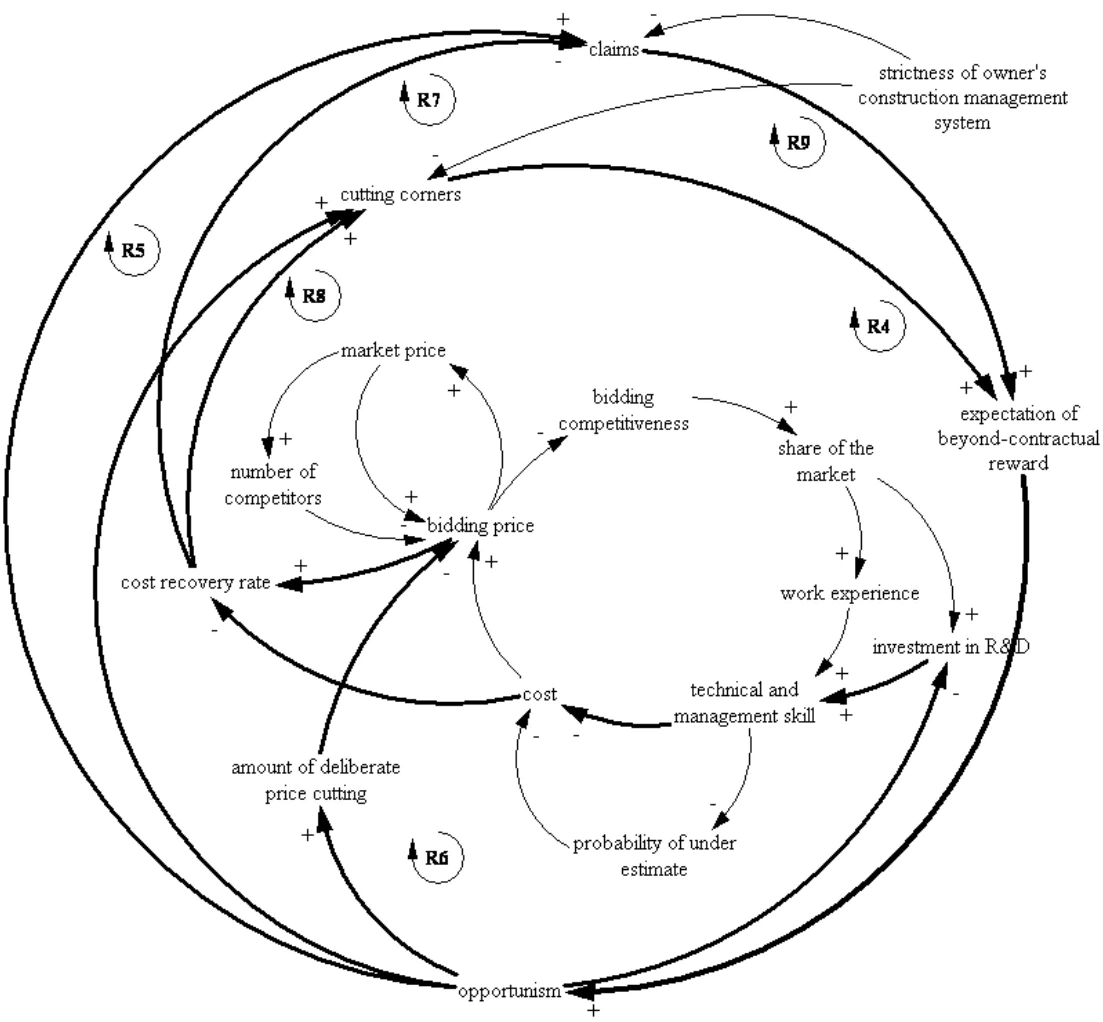


Figure 4: Contractors' opportunistic behaviour under competitive bidding system

The reinforcing feedback loops, R6 and R7

There are two other reinforcing loops with adverse effects shown in Figure 4 as R6 and R7. When a contractor deliberately cuts a price, the cost recovery rate will decrease, making the contractor need to cut corners and raise claims in the project execution phase for survival. After a period of time and with accumulated experience, the contractor may have confident expectations of BCR and offer lower prices for future projects. This reinforcing feedback process will constantly intensify contractors' opportunism and adverse effects.

The reinforcing feedback loops, R8 and R9
Rooke *et al*. (2004) proposed that opportunistic contractors tend to expend more effort on generating profit from claims than from improved construction methods. Accordingly, it is logical to infer that opportunism will discourage contractors' willingness to improve their capabilities, especially when the award price is unreasonably low and most contractors survive upon BCR. The phenomenon is described as reinforcing feedback loops as R8 and R9.

This section introduces six adverse reinforcing feedback loops hidden within the competitive bidding system. Lo *et al*. (2007) have studied this unintended situation called contractors' opportunistic bidding behaviour and analysed its effects on the construction industry through simulation. That paper concluded that opportunistic bidding can seriously damage the ideal functions of the competitive bidding system. In other words, the R1, R2, R3, B1, B2 and B3 can stagnate. Contractors' opportunistic bidding behaviour thus becomes the critical cause of abnormally low bids, poor project quality, and the failure of the competitive bidding system.

CURRENT PRACTICES TO AVOID ABNORMAL LOW-BIDS

Incorporating a pre-qualification procedure into competitive bidding system
In most countries, a selective procedure called a 'pre-qualification' (PQ) is employed to screen out those contractors having low capabilities; the remaining bidders are then evaluated for further consideration (Topcu 2004). Through the PQ procedure, the abnormally low bids should be minimized (Ng and Skitmore 1999).

It seems reasonable to expect that high PQ requirements will result in a competent contractor and consequently deliver a quality product in a timely manner and within budget. However, Lo *et al*. (1999) proposed that improper high PQ requirements can increase (a) the owner's project expenditure because of lack of competition; and (b) the administration cost because of unsuccessful tendering. From a system perspective, the use of PQ may raise a contractor's bidding price, owing to less competition. This may increase a contractor's cost recovery rate and reduce the contractor's BCR seeking behaviour for the deficits, so loops R6–R9 may be remedied. However, there is no guarantee that the pre-qualified contractor will not seek to obtain BCR. Since BCR seeking is the natural behaviour of a profit-maximizing organization, loops R4 and R5 are not resolved by the PQ strategy.

Screening the likely abnormally low bids
Previous studies have developed sophisticated decision models to reject or accept the lowest project bid depending on whether or not the lowest bid price is considered reasonable (Crowley and Hancher 1995a; Crowley and Hancher 1995b; Crowley 1997; Hiyassat 2001). Wang *et al*. (2004) have proposed another method for evaluating competitive bids. A predetermined project ceiling price is used as a threshold or reference point for accepting or rejecting bids (Wang *et al.* 2006).

Assume that the project owners are capable of detecting and screening out all abnormally low bids. So there is no concern about a contractor's accidental underestimate or deliberate price cutting and the cost recovery rate is enhanced. From a system perspective, however, these efforts only remedy the adverse effects of loops R6–R9 aforementioned in Figure 4. The loops R4 and R5, which are caused by the contractor's opportunism, are still an unsolved problem.

EFFECTS OF QBS SYSTEM ON CONTRACTORS' BEHAVIOUR

Compared with the competitive bidding system, the QBS system is designed to find qualified and competent contractors instead of lowest bidders. Besides price, non-price criteria, such as the contractor's past performance, work experience, technical and management skills, etc., are adopted in the contractor selection process. QBS is also recognized as a 'best value' selection system, while some studies distinguish best value selection and the QBS system on whether the price is included or not in the selection criteria (Beard *et al.* 2001; Wardani *et al.* 2006). From a system perspective, the QBS will lead contractors to form seven additional feedback loops as follows:

The reinforcing feedback loops, R1b–R3b

The inclusion of non-price criteria generates reinforcing loops that lead contractors to increase competitiveness and expand their businesses in a positive way. An experienced contractor can gain more competitiveness in the selection phase and consequently obtain more share of the market and more work experience, as loop R1b shows in Figure 5. In addition, QBS usually requires contractors to submit a technical proposal and brief on how projects are planned and what construction methods and materials are chosen. Contractors can create their competitiveness through innovative designs, materials and construction methods, so as to raise the project quality and better satisfy owners' need (Yan *et al.* 2005). Accordingly, reputable contractors with better technical and management skills will be able to prepare quality proposals and win contracts. Consequently, they have more chances to further improve technical and management skills through execution of works and R&D. These positive reinforcing feedback loops are marked as R2b and R3b in Figure 5.

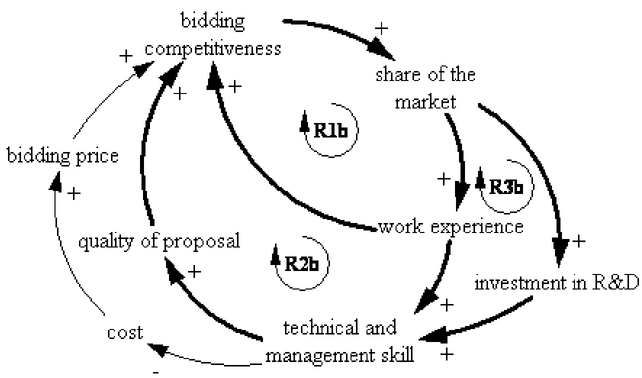


Figure 5: The feedback loops of contractor's behaviour under QBS (a)

The reinforcing feedback loops, R4b–R7b

An exceptional advantage of the QBS system is its capability to deal with opportunistic bidding. Once a contractor's past performance becomes an important criterion to evaluate a contractor's qualification, contractors are forced to minimize corner-cutting behaviour and claims, so as to improve their performance record and competitiveness. This behavioural tendency forms some reinforcing feedback loops: R4b, R5b, R6b and R7b, which provide contractors with an incentive to respect their performance in the construction phase (see Figure 6). With the functions of loops R4b, R5b, R6b and R7b, an opportunistic contractor who tends to obtain BCR will face the loss of competitiveness owing to unfavourable performance record. Since the weighting criteria evaluation method is usually used to select the contractor, the effects of reducing opportunistic bidding can be significantly enhanced as the project owner puts more weight on evaluating a contractor's past performance.

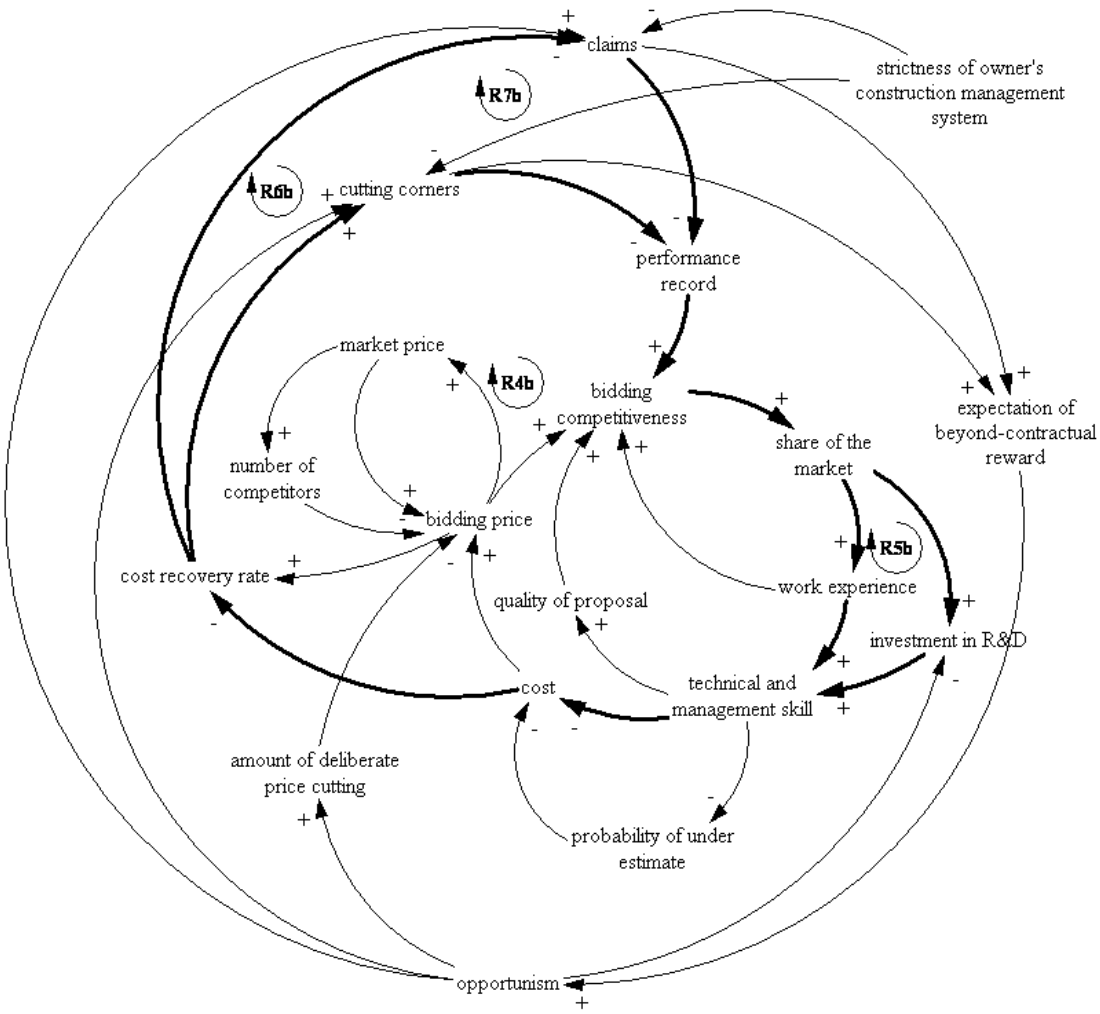


Figure 6: The feedback loops of contractors' behaviour under QBS (b)

STRATEGIES FOR PROJECT OWNERS

According to the systematic analysis of contractors' behaviour, this research derives several strategies for project owners to promote project success.

1. Improving the construction management system. Previous research has indicated that the key motivation in contractors' opportunistic bidding is the potential BCR in the current construction management system (Lo *et al*. 2007). Since contractors' expectation of BCR can intensify their opportunism, reducing the possibility and amount of BCR should always be the most important task for project owners. The owners must put more efforts into improving their construction management system, including the soundness of contracts and strictness of construction supervision. From a system perspective, once the strictness of owners' construction management system is improved, adverse loops R4–R8 may become obsolete.

2. Increasing the importance of non-price criteria in the selection process. The use of non-price criteria has been demonstrated to increase the competitiveness of the non-opportunistic and competent contractors. The owners are encouraged to use more non-price criteria in the selection process. Some useful criteria should include the contractor's past performance, financial capability, work experience, quality of key personnel and technical proposals. Besides,

the owners need to weigh those non-price criteria more so as to enhance the effects of QBS. The benefits of this strategy are interpreted in the aforementioned causal loop diagrams as loops R2–R3 and R1b–R3b.

3. Implementing prompt contractor performance rating systems. It should be noted here that the inclusion of the contractor's past performance has exceptional usefulness in reducing the contractor's willingness to sacrifice project quality and raise claims. The function is demonstrated as loops R4b–R7b. To make those loops more effective, the owners need an objective and sensitive performance rating system. Several researchers are working on this line of research such as contractors' performance prediction (Alarcon and Mourgues 2002), contractor's quality performance assessing model (Yasamis *et al.* 2002), and quality-based contractor rating model (Minchin *et al.* 2005).

CONCLUSIONS

The competitive bidding system and QBS are two mainstreams of contractor selection today. It is worthwhile to comprehensively study the impacts of these two systems on contractors' behaviour and the development of the construction industry. However, too often we have investigated these two systems on the 'events level'. This 'events cause events' orientation doesn't lead to very powerful ways to understand the evolution of contractors' behaviour or alter undesirable situations. With a systems thinking approach, this research takes an alternative viewpoint that the internal structure of the system is often more important than external events in generating the problem. Therefore, instead of showing how one set of events causes a problem, this research focuses on discovering a long-term pattern of contractors' behaviour in the construction market. This paper explicitly depicts the causal relationships between the use of different contractor selection systems and contractors' competitive behaviour. Several important feedback loops of contractors' behaviour are discovered and analysed. Through the understanding of the whole system of contractors' behaviour, project owners' managerial policies can be evaluated and improved.

REFERENCES

Alarcon, L F and Mourgues, C (2002) Performance modeling for contractor selection. *Journal of Management in Engineering*, **18**(2), 52–60.

Beard, J, Loukakis, M C and Wundram, E C (2001) *Design-build: planning through development*. New York: McGraw-Hill.

Capen, E C, Clapp, R V and Campbell, W (1971) Competitive bidding in high risk situations. *Journal of Petroleum Technology*, **23**(6), 641–53.

Carlton, D W and Perloff, J M (2000) *Modern industrial organization*. 3ed. Reading, MA: Addison-Wesley Longman, Inc.

Carr, R I (1983) Impact of number of bidders on competition. *Journal of Construction Engineering and Management*, **109**(1), 61–73.

Crowley, L G (1997) Robust statistical estimators for use within competitive bid data. *Journal of Construction Engineering and Management*, **123**(1), 53–63.

Crowley, L G and Hancher, D E (1995a) Evaluation of competitive bids. *Journal of Construction Engineering and Management*, **121**(2), 238–45.

Crowley, L G and Hancher, D E (1995b) Risk assessment of competitive procurement. *Journal of Construction Engineering and Management*, **121**(2), 230–7.

Doyle, W J and DeStephanis, A (1990) Preparing bids to avoid claims. *In*: R F Cushman and W J Doyle (Eds.) *Construction bidding law*. New York: John Wiley & Sons, Inc.

Friedman, L (1956) A competitive bidding strategy. *Operation Research*, **4**(1), 104–12.

Fu, W K, Drew, D S and Lo, H P (2003) Competitiveness of inexperienced and experienced contractors in bidding. *Journal of Construction Engineering and Management*, **129**(4), 388–95.

Gransberg, D D and Ellicott, M A (1996) Best value contracting: breaking the low-bid paradigm. AACE Transactions.

Grogan, T (1992) Low bids raise hidden costs. *Engineering News-Record*, **228**(13), 30–1.

Gruneberg, S L and Ive, G J (2000) *The economics of the modern construction firm*. Basingstoke: Macmillan.

Hillebrandt, P M (2000) *Economic theory and the construction industry*. 3ed. Basingstoke: Macmillan.

Hiyassat, M A (2001) Construction bid price evaluation. *Canadian Journal of Civil Engineering*, **28**(2), 264–70.

Ho, S P and Liu, L Y (2004) Analytical model for analyzing construction claims and opportunistic bidding. *Journal of Construction Engineering and Management*, **130**(1), 94–104.

Lo, W, Krizek, R J and Hadavi, A (1999) Effects of high prequalification requirements. *Construction Management and Economics*, **17**(5), 603–12.

Lo, W, Lin, C L and Yan, M R (2007) Contractor’s opportunistic bidding behaviour and equilibrium market price level in construction market. *Journal of Construction Engineering and Management*, forthcoming.

Minchin, R E, Gary, R and Smith, M (2005) Quality-based contractor rating model for qualification and bidding purposed. *Journal of Management in Engineering*, **21**(1), 38–43.

Ng, S T and Skitmore, R M (1999) Project owner and consultant perspectives of prequalification criteria. *Building and Environment*, **34**(5), 607–21.

Ngai, S C, Drew, D S, Lo, H P and Skitmore, M (2002) A theoretical framework for determining the minimum number of bidders in construction bidding competitions. *Construction Management and Economics*, **20**(6), 473–82.

Rooke, J, Seymour, D and Fellows, R (2004) Planning for claims: an ethnography of industry culture. *Construction Management and Economics*, **22**(6), 655–62.

Runeson, G (2000) *Building economics*. Geelong, Australia: Deakin University Press.

Runeson, G and Raftery, J (1998) Neo-classical microeconomics as an analytical tool for construction price determination. *Journal of Construction Procurement*, **4**(2), 116–31.

Topcu, Y I (2004) A decision model proposal for construction contractor selection in Turkey. *Building and Environment*, **39**(4), 469–81.

Wang, W C (2004) Supporting project cost threshold decisions via a mathematical cost model. *International Journal of Project Management*, **22**(2), 99–108.

Wang, W C, Wang, H H, Lai, Y T and Li, C C (2006) Unit-price-based model for evaluating competitive bids. *International Journal of Project Management*, **24**, 156–66.

Wardani, E I, Messner, I and Horman, J (2006) Comparing procurement methods for design-build projects. *Journal of Construction Engineering and Management*, **132**(3), 230–8.

Williamson, O E (1985) *The economic institutions of capitalism*. New York: Free Press.

Winch, G M (2000) Institutional reform in British construction: partnering and private finance. *Building Research and Information*, **28**(2), 141–55.

Yan, M R, Lo, W and Lin, C L (2005) Impacts of design-build delivery system on the construction industry in Taiwan. *In*: *Proceedings of the First International Conference on Construction Engineering and Management (ICCEM)*, 16–19 October 2005, Seoul, Korea. Korean Institute of Construction Engineering and Management, 1007–12.

Yasamis, F, Arditi, D and Mohammadi, J (2002) Assessing contractor quality performance. *Construction Management and Economics*, **20**(3), 211–23.

ICT IN CONSTRUCTION ENGINEERING AND MANAGEMENT: POTENTIAL AND PROMISES

Irtishad Ahmad[1] and Maung Sein[2]

[1]*Department of Construction Management, Florida International University, Miami, Florida, USA*
[2]*Department of Information Systems, Agder University College, 4604 Kristiansand, Norway*

While the construction engineering and management (CEM) community has embraced information and communication technology (ICT), the interest in both practice and academia has been less than thorough. In particular, the academic community is criticized for not addressing the importance of ICT adequately either in research or teaching. This paper reports the results of two surveys, one dealing with the teaching mission of academia and the other with its research mission. The results are not comforting as they confirm the lack of attention paid to ICT. In discussing these findings, suggestions are made for affectively incorporating ICT into the academic milieu of CEM.

Keywords: information management, information technology, construction education, action research, construction organizations.

INTRODUCTION

In today's competitive environment, construction engineering (CE) and construction management (CM) organizations are increasingly dependent on information and communications technology (ICT). This dependence is not only to stay competitive using the latest technology but also to innovate and create new ideas. The function of academia should therefore be two fold: First, it should create knowledge on the use of ICT in CEM by conducting rigorous and relevant research and informing practice. Second, it should propagate this knowledge through educating the future practitioners by incorporating ICT into curricula to meet the growing need for professionals who are competent in ICT.

There is also a seeming lack of conceptual clarity on the role of ICT in CEM. In published articles, for instance, ICT is viewed simply as a tool to automate the construction and management processes. Its transformational potential is not dealt with. Ahmad *et al*. (1995) noted that design and construction organizations can achieve integration of various construction activities by redesigning many of their organizational functions and processes and IT can facilitate redesigning of these processes. Far-reaching impacts of ICT on construction organizations in transforming and re-designing organizational structures, management processes, individual roles and business strategy are seldom covered in the published literature.

In this paper, an attempt is made to sort through these issues by surveying graduate curriculum around the world and then sampling the papers published in leading CEM journals over a decade. The results are then discussed in the light of the potential of

[1] ahmadi@fiu.edu

ICT in helping CEM to innovate and radically change the construction management processes. Specific suggestions are made in this direction.

THE SURVEYS

ICT in CEM curriculum

In this survey, the graduate curriculum and individual courses of 118 universities were examined to assess the degree to which ICT was addressed. Of the total number of universities surveyed, 66 were from North America (56 from US), 23 from Europe (20 from UK), 19 from Asia (six from China and five from Japan) and 10 from other areas (eight from Australia). The curriculum information for the graduate level courses was obtained through the website of the universities. The detailed course descriptions and the specific topics covered in these courses were examined. The departments surveyed were those that were related to construction in some form or other. Examples include civil engineering, construction management and, building science. The full details of the findings are reported elsewhere (Ahmad *et al*. 2006). The following is a summary of the findings of the survey:

- ICT is a small part of the curriculum in CM and CE:
  - 45% of universities do not offer any ICT-related course.
- The most common topics in the courses include:
  - Computer-aided engineering (CAE). Examples are “Computer Applications in Structure”, “Computer Methods in Transportation” or “Computer Applications in Construction Engineering”.
  - Visualization, simulation and modeling (VSM) includes different construction processes like transportation modeling, traffic simulation and virtual design.
  - Human-oriented courses: artificial intelligence, knowledge-based expert systems, decision support system, fuzzy logic applications.
  - Use of Geographic Information Systems applications.
  - General content such as information technology for construction, computers in construction, construction information.
- Popular and current topics such as e-business and web-based applications are not commonly offered.
- When covered, focus is purely functional (e.g. introduction to tools):
  - They aim to provide ICT-based solutions for general engineering problems rather then being construction-industry oriented.
- Vital aspects that are ignored include:
  - Organizational and process change.
  - Impacts of ICT on the industry, its organizations and the fundamental issues of construction.

The conclusion that can be drawn is that CE and CM institutions are more interested in introducing the concept of a tool and its practical implementation rather than providing in-depth conceptual understanding. While it is difficult to incorporate in-depth technical education on ICT in a typical CEM curricula the argument can be made that the current extent of coverage is not adequate and is unproductive. It does not lead to thinking about innovative use of ICT and the realization of the potential of ICT for CEM.

ICT in CEM journals

In this survey, all articles published during the time period 1996–2006 in five leading journals in construction were examined to find out how many of them were ICT related. This information was collected by conducting keyword search electronically using "information technology" as the keywords, except for the *ASCE Journal of Computing in Civil Engineering*. (It was found that the list of designated keywords of these journals does not include "information and communication technology," as used in this paper, but "information technology".) It should be noted that the results of the search depended on whether the keywords "information technology" were chosen by the author(s) to describe their papers. It is quite possible that several -elated articles were not included in the electronic count reported in this paper, because "information technology" was not included in the list of keywords of those papers. However, the number of such papers is not very high, except for the *ASCE Journal of Computing in Civil Engineering*. The initial count of ICT-related articles published in this journal was unrealistically low (around 5%). To delve deeper, the titles and abstracts of the articles were examined. As a result, the percentage rose to just under 19%. It is quite possible that authors of these articles opted for more appropriate and relevant keywords related to computing or computer applications rather than "information technology" since there is a maximum limit on the number of keywords that can be used for a paper. The findings, shown in Table 1, reveals that only about 5.24% of all articles published in these five leading journals are ICT related.

Table 1: ICT-related journal articles in leading construction journals during the last decade (1996–2006)

Journal title	Total number of articles published	Number of IT-related articles	Percentage of IT-related articles
Journal of Construction Engineering and Management (ASCE)	854	18	2.11%
Journal of Management in Engineering (ASCE)	286	4	1.40%
Journal of Computing in Civil Engineering (ASCE)	353	67	18.98%
Automation in Construction (Elsevier)	606	49	8.09%
Construction Management and Economics (Routledge)	688	8	1.16%
Total	2787	146	5.24%

The conclusion is clear. There are very few ICT-related papers published in the mainstream construction journals. A quick scanning of the titles of these articles substantiates the earlier contention in this paper that most of these papers and research works describe or present a tool or a process rather than the role of ICT in transforming or revolutionizing the process or the organization.

In addition to the journals mentioned above, a journal titled ITCon or Information Technology in Construction debuted in 1995. The publisher was the Royal Institute of Technology (Sweden). ITCon in 2005 combined with IT-AEC journal and since then is being published by the International Council for Research and Innovation in Building and Construction (CIB). The nature of the articles published in this journal (www.itcon.org) is not much different from the most ICT-related papers published in the journals discussed above.

DISCUSSION OF FINDINGS

Taken together, the findings of the two studies suggest that the potential to utilize ICT to bring about fundamental changes in the construction industry remains unrealized. This is disappointing. The challenges facing the academia in CEM are:

- How can ICT and CM/CE be integrated in the course curriculum in colleges and universities?
- How can research be conducted and the results disseminated to both academia and practice on the potential of ACT in altering the practice of CM and CE and do away with archaic rules and regulations?

In the following, these questions are examined in detail.

Potential for ICT in CM

ICT can contribute to CEM discourse at different levels. In the Information Systems literature, it is said that ICT enables one to (a) do things better and (b) do better things. The first is related to increasing efficiency and effectiveness of existing processes in an organization or an industry. The second addresses the basic aspects of these processes and looks at making revolutionary changes by employing innovative processes. These two potentials are discussed below.

Doing things better

In this context, ICT is conceptualized as a tool and a means to support existing processes. There have been some previous attempts in the CEM literature to study this aspect of the role of ICT. Ahmad *et al*. (1995) proposed that the capabilities needed in CEM could be grouped as follows:

- Communications systems – tools or techniques that support project or organizational communication and collaboration like networking and e-business.
- Data accessibility – systems focusing on data capturing, storage, retrieving and transmitting.
- Common systems – systems used for decision making and technical analysis.

In construction, communications or exchange of information is one of the most important functions. The success of this function depends to a large extent on the quality and accessibility of data, as well as on the efficiency and effectiveness of the systems designed to process data. These are basically automation tools and can contribute to increased efficiency. In other words, tasks performed by manual methods if delegated to computer-assisted environments can improve efficiency, particularly in the area of information processing. They do not necessarily enhance effectiveness of the organization.

Doing better things
Here the focus is on the potential of ICT in re-engineering CEM practices. The question addressed is “Can ICT help us examine ways of altering the practice of CEM and do away with archaic rules and regulations?”

This issue has been extensively treated in the management and business literature during the last few decades in the form of business process reengineering (BPR). First popularized in the 1980s by pioneers such as Davenport and Hammer (e.g. Davenport 1993; Hammer and Champy 1993), the essence of BPR is that basic processes and practices in business organizations can be radically changed to increase effectiveness of the organization. These processes can even be totally deleted to be replaced by new processes. The enabler for such re-engineering processes is ICT.

A similar approach can be taken in CEM. Rules and regulations to govern the relationships and contractual obligations of the various entities (owner, contractor, engineer, etc.) have existed for years and continue today. It is time to question whether these practices are still necessary today. Can ICT contribute to changing these rules?

To illustrate, the practice of awarding contracts on the basis of low bids can be considered. The practice is based on the assumption that awarding contracts to the lowest bidder ensures fairness and promotes innovation while keeping the cost to a reasonably low level. The practice implies that the scope of the project is fully defined and hence, the design, drawings and specifications can be fully developed before the project is let out for bidding. This is known as design-bid-build process in which the functions of design and construction are kept separate. The contractor is hired after the design is completed. Project scopes, however, are rarely developed to their fullest extent before bidding. Change orders are inevitable as the owner and the designers usually continue to make changes even after the contract is finalized. The final cost of the project frequently exceeds the contracted price (lowest bid). Now it is a generally accepted notion in the US construction industry that the principle of awarding contracts on the basis of low bids failed to produce its intended results. In the US, even the government sectors that normally adhere to this practice, are increasingly switching to the design-build principle. Under this process, both design and construction are typically carried out by the same entity. The design function does not have to be completed before construction can begin, input from the construction people can be incorporated in the design, and usually coordination between the two (design and construction) functions is greatly improved. It should be noted that under this practice both the designer and the contractor are sharing the project risk, not just the contractors as in the case of design-bid-build principle. The practice of design-build principle can be enhanced by effective use of ICT. An effective and meaningful integration between the two major functions – design and construction – can be achieved by utilizing ICT. In order to achieve meaningful advantages offered by ICT, however, the industry norms and traditions, such as the reliance on design-bid-build principle, must be scrutinized critically. Only then can the real advantage offered by ICT be realized. In this case, ICT plays the role of the enabler for a major paradigm shift from design-bid-build to design-build.

Another fundamental aspect that ICT has the potential to alter is the perspective of the construction project team. Essentially, a project team is a temporary virtual organization (Ahmed and Sein 1997). A variety of organizations and businesses combine to form a project organization whose specific and perhaps only objective is to complete the construction project. The team then disbands. However, even though this team has a relatively short life, it has all the characteristics of an organization. It is a form of "extended enterprise" (Benbasat and DeSanctis 2000). Thus, much can be learned from research on organization theory. The IS literature has a long tradition of examining the role of ICT in effecting organizational structure, form and governance.

Based on the economic theory of organizations, three forms are popular: markets, hierarchy and networks. Traditionally, construction teams are based on markets. Each party, such as a subcontractor independently buy and sell services to other subcontractor or the main contractor on the basis of economic self-interest. These are enforced by legal instruments. However, since all contingencies cannot be covered in a contract, disputes frequently occur. Moreover, as Jarvenpaa *et al*. (2000) point out, it is not a good mechanism for transfer of learning and is susceptible to opportunism by a contractual partner.

A more suitable form for a construction team is a network organization. This is a flexible form and is based on the premise of equality, communication, reciprocity and fair exchange (Jarvenpaa *et al*. 2000). It is also a better form than market for exchange of services whose prices are not easily measured or foreseen, such as in construction. Perhaps the main advantage of a network form is its flexibility. A specific form of networks, especially germane to construction is "production networks" (Powell 1991) where temporary teams are formed for very specific purposes rapidly and then disbanded.

The glue that holds a network organization is building relationships. ICT can play a vital role in this. There is a requirement for common systems that span these diverse partners. Today's technology is teeming with such systems or platforms. Internet technology can be used to ease transfer of information and even data through use of say, XML. Mobile and hand-held devices provide easy ways of accessing common databases and communication.

In essence then, it is not the technology that is missing here; it is the social and human aspects that can be seen as a barrier in exploiting the opportunities offered by ICT. As an example, the concept of virtual organizations, introduced earlier, is dependent on trust. The team participants in a construction project must trust each other and must share the same objectives for the virtual project teams to work effectively. They must be able to overcome the barrier of time and distance by ICT. ICT here satisfies the necessary condition, but is not sufficient. It is not the perfection of technology that can make the concept of virtual teams work perfectly, but the presence of human aspects, such as trust and understanding.

The construction industry is coming to the realization, albeit slowly, that ICT – if viewed as disparate tools – cannot be used effectively (Sawyer 2007). The organizational structures need to be aligned to fit with the ICT infrastructure. Azhar's (2005) research on data warehousing demonstrates that organizational units must be restructured for effective implementation of data warehousing. Thus, it is imperative to understand that ICT cannot be installed in organizations without considering its impacts on interactions among organizational units and on the people working in these units.

These questions have also been addressed by a handful of scholars in construction. For example, Ahmad *et al*. (1995) pointed out three broad areas where construction organizations can focus in order "to do better things". They are:

- Re-engineering (same as BPR, mentioned earlier) – for example, redesigning organizational structure for effective deployment of ICT infrastructure.
- Decentralization of the power of decision making – for example, empowering the middle management with decision making authorities by providing necessary information in a timely manner through ICT.
- Development of integrated information processing systems – for example, sharing of same site data by multiple contractors from an integrated source of information.

Discussion

The twin challenges facing the academia in CEM is to improve the educational offerings related to coverage of ICT and to improve research efforts in this topic. In the following, these two aspects are discussed further.

To improve education

Obviously, the current state-of-affairs in terms of ICT in CEM education needs improvement. To that extent, the following suggestions are made.

- Strengthen existing courses to cover all ICT capabilities and higher knowledge levels.
- Develop new courses, both mandatory and elective, on ICT and construction.
- Develop tracks concentrating on ICT in current CM and CE programmes.
- Develop specialized graduate programmes on ICT in construction.
- Develop industry-wide model curricula that universities can use.

Some initiatives have already been taken or suggested. The curriculum survey reported earlier found some noteworthy course offerings on e-business related areas. For example, Massachusetts Institute of Technology in USA has a course on e-commerce and internet applications in real estate. Carnegie Mellon University, also of USA, has courses on “e-construction” dealing with such subjects as the current status of e-business applications and business models and designing/building Internet-enabled e-construction processes and systems. Ahmad et al. (2006) proposed a course on Data Warehousing for Construction Management that covers not only the ICT capabilities needed in CM, but also knowledge at levels above tools (addressing not only “what?” But also “how?” and “why?”).

To improve research

A key challenge is motivating CEM researchers to carry out research on the role of ICT in CEM. Academics, as any other group, respond to reward system, whether in tangible or intangible form, and have extrinsic or intrinsic motivation. Both aspects are tied up to a great extent on publications. Publication is a key, if not the most important, criterion for tangible and extrinsic rewards such as promotion. They also serve intrinsic motivation and as intangible reward by providing the satisfaction of contributing to the body of knowledge in CEM and, in doing so, gain renown and respect of peers. The onus is therefore on the current “mainstream” CM literature to set a platform for this stream of research. Such is not the case currently, as revealed by the survey reported in this paper.

Chief Editors of prestigious journals in the field, such as the celebrant *Construction Management and Economics*, can encourage submissions on the topic. Special issues on different aspects of ICT can be published. On a more permanent basis, there can be sections on ICT related topics in every issue. Finally, appointing researchers with ICT background to editorial boards can be a motivating factor.

In addition, it appears that there is a widening gap in the way ICT is perceived for application between the practitioners and academia. This issue involves the classical challenge of transferring research results into practice. CEM is in an enviable position of close collaboration between academia and practice. A vast number of academics are also practitioners through consultancy work. The irony is that such academics tend to move away from research. This is disappointing because a research method exists that seems tailor made for CEM. That is action research where the emphasis is on practical problem solving and knowledge creation at the same time. The essence of action research is captured in this definition:

> "Action research simultaneously assists in practical problem-solving and expands scientific knowledge, as well as enhances the competencies of the respective actors, being performed collaboratively in an immediate situation using data feedback in a cyclical process aiming at an increased understanding of change processes in social systems and undertaken within a mutually acceptable ethical framework." (Hult and Lennung 1980)

Thus, action research is building/testing theory within context of solving an immediate practical problem in real setting. It combines theory and practice, researchers and practitioners, and intervention and reflection. Collaboration with practitioners and their learning is vital. It is emphasized strongly that action research is not consulting: it is action, but still research. In essence, it is "research in action."

The IS academic community, stung by long standing criticism about the lack of relevance of research for practice, recently concluded that there is a need to adopt research methods that are "proactive" in nature (Cole *et al*. 2005). Such methods aim at first changing reality and then studying its effects. This is in stark contrast to "reactive" methods that focus on the existing reality (such as surveys and qualitative interpretive case studies). The two methods identified as proactive are design research and action research (Figueiredo and Cunha 2007; Cole *et al*. 2005). Design research is of course what the CEM community does. It is proposed here that the community adopt action research as well.

One can immediately see why action research is perfect for CEM. The close ties between academia and practice and through "practicing academics", the groundwork for mutual informing already exists. All that is needed is to conceptualize all consultancy work as potential action research projects. To that end, this methodology can be taught at the graduate level and workshops and seminars can be arranged at conferences. One conference that has already started these workshops is CITC (Construction in the Twenty-first Century).

CONCLUSIONS

The main message in this paper is that the field of construction is in danger of missing out on the transformational capabilities of ICT. Simply viewing ICT as a tool to support processes in construction is underutilizing the vast potential of this revolutionary technology. Innovative ideas and implementations already exist but these are fragmented and isolated instances. It is essential that these efforts be integrated and become part of the general body of knowledge in construction. This paper is a step in that direction.

REFERENCES

Ahmad, I, Sein, M K, Ahmed, S M and, Artuk U (2006) Developing Managers of Tomorrow: The State of ICT in Construction Engineering Education. *In: Proceedings of the 15th PICMET* Istanbul, Turkey.

Ahmad, I U and Sein. M K (1997) Building construction project teams for TQM: A Factor Element Impact Model, *Construction Management and Economics*, **15**, 457–67.

Ahmad, I, Russell, J S and Abou-Zeid, A (1995) Information Technology (IT) and Integration in the Construction Industry. *Construction Management and Economics*, **13**, 163–71.

Azhar, S (2005) *Information Systems to Support Decision-Making in Construction Owner Organizations: A Data Warehousing Approach*, Doctoral Dissertation, Florida International University.

Benbasat, I and DeSanctis, G (2000) “Communication challenges”: A value network perspective. *In:* G W Dickson and G DeSanctis (eds.) *Information Technology and the Future Enterprise: New Models for Managers*. Upper Saddle River, NJ: Prentice Hall, 144–62.

Cole, R, Purao, S, Rossi, M and Sein, M (2005) Being Rigorously Relevant: Design Research and Action Research in Information Systems. *In: Proceedings of the 26th International Conference on Information Systems*, Las Vegas, NV, 325–36

Davenport, T H (1993) *Process Innovation* **-** *Reengineering Work through Information Technology*. Cambridge, MA: Harvard Business School Press.

Figueiredo, A D and Cunha, P D (2007) Action Research and Design in Information Systems: Two Faces of a Single Coin. *In:* N. Kock (Ed.) *Information Systems Action Research: An Applied View of Emerging Concepts and Methods*. Springer.

Hammer, M and Champy, J (1993) *Reengineering the Corporation-A Manifesto for Business Revolution*. New York: Harper Collins.

Hult, M and Lennung, S-A (1980) Towards a definition of action research: A note and bibliography. *Journal of Management Studies*, **May**, 241–50.

Jarvenpaa, S, Tiller, E H and Kirsch, L J (2000) Bureaucracy: The Global network organization of the future. *In:* G. W. Dickson and G. DeSanctis (Eds.) *Information Technology and the Future Enterprise: New Models for Managers*. Upper Saddle River, NJ: Prentice Hall, 239–60.

Powell, W W (1991) Neither market nor hierarchy: network forms of organization. In G. Thompson *et al*. (Eds.) *Markets, hierarchies & networks: The coordination of social life*. London: SAGE Publication.

Sawyer, T (2007) Innovative tools help companies cut the data beast down to size: Vendors offer a range of new strategies to capture and leverage enterprise data. *Engineering New Record*, 26 February, 26–28.

A MATRIX FOR SELECTING APPROPRIATE RISK MANAGEMENT TECHNIQUES IN THE BUILT ENVIRONMENT

Doug Forbes[1], Simon Smith[2] and Malcolm Horner[1]

[1]*CMRU, Division of Civil Engineering, University of Dundee, DD1 4HN, UK*
[2]*Institute for Infrastructure and the Environment, School of Engineering, University of Edinburgh, UK*

Within the built environment, there is a discontinuity between risk management techniques used in practice and those developed and researched in academia. Organizations commonly apply a few selected techniques to a range of problems. This could be because of a lack of knowledge and understanding of when a technique can be appropriately used. To overcome this, a risk management matrix is proposed whose purpose is to provide guidance on which technique is appropriate in which context. This characterizes problems by: (1) external and internal risks – defined by a PESTLE Model; (2) the risk owner; and (3) the project stage. A second stage is used to define the data used as fuzzy, incomplete or random. The two-dimensional matrix has been developed from 179 example applications of techniques in the literature. The matrix highlights a focus on techniques for economic issues. It also identifies a lack of examples of techniques applied to political, social, legal and technological risks. The matrix is an effective tool for selecting the appropriate techniques in risk management, but gives no indication of frequency with which techniques have been applied previously. It also highlights further gaps in the current techniques and provides avenues for focusing future research.

Keywords: decision support, risk techniques.

INTRODUCTION

The objective of this work is to create a support tool for selecting appropriate risk management techniques. The construction industry is subject to many risks (Perry and Hayes 1985; Flanagan and Norman 1993) and a wide range of available techniques is identified in the literature. However, very few of these are used in practice. One reason for this could be that there is a lack of knowledge and understanding of when a technique can be applied. To overcome this, a matrix is developed from examples in the literature.

The development of the matrix relies on a common framework to identify problems. This research uses the PESTLE (political, economic, social, technological, legal and environmental) model, which has been previously applied to risk management (HM Treasury 2004), and the FIR (fuzziness, incompleteness and randomness) model from construction systems (Blockley and Godfrey 2000) to create problem characteristics.

[1] d.r.forbes@dundee.ac.uk

RISK MANAGEMENT BACKGROUND

Definitions used in risk management

The construction risk management literature has varied terms for risk management. Definitions have been produced for this research that allow rigour and consistency. Risk can be defined as exposure to a decision that has an uncertain outcome. The outcome and consequence may be favourable or adverse. This definition incorporates the three elements which are considered in risk: (1) likelihood of an event occurring; (2) outcome of an event and (3) duration of an event (Jaafari 2001; Kaplan *et al.* 2001; Hillson 2002; Pate-Cornell 2002; HM Treasury 2004).

The research is concerned with risk management techniques. These techniques are applied at first three stages of the risk management cycle: identification, estimation (analysis stage I) and evaluation (analysis stage II) (Perry and Hayes 1985; Flanagan and Norman 1993; Baker *et al.* 1999). The response and monitoring stages are not considered here, as specific techniques are not applied.

The three stages are defined as: (i) identification is the process by which risks are recognized and recorded; (ii) estimation assessed the magnitude of the risk; and, finally, (iii) evaluation is the process of calculating and defining the combined risk attributes.

Use of risk management techniques

A study carried out by Akintoye and Macleod (1997) reviewed the risk management techniques used in practice by contractors and project management practices. This concluded that the usage rates were very low for all but a few techniques. They found that 77% of contractors and 100% of project management practices used intuition and experienced-based techniques. Subjective probability, Monte Carlo Simulation and sensitivity analysis were used to a limited extent. More ‘complex’ techniques were seldom used, and some were even unknown by the respondents (e.g. Stochastic Dominance). The authors give eight reasons for the lack of use. Most of these relate to a lack of confidence in the techniques, and or their lack of applicability to construction. Similar results were obtained from an Australian study by Bajaj *et al.* (1997) for identification techniques.

These findings have been confirmed over time and a review in 2003 of risk management in UK cost consultants found that probability and consequence was considered by most, as was Monte Carlo Simulation (Wood and Ellis 2003). However, very few carry out a sensitivity analysis and only one out of the 11 consultants sampled used any form of decision, fault or event tree. More ‘complex’ methods were not even considered (e.g. influence diagrams, neural networks).

These studies show a reliance on a small number of techniques. Additionally, these techniques have focussed research away from ‘softer’ risks such as the social and political (Edwards and Bowen 1998). However, the fears of many practitioners that a technique may not be applicable to construction are more likely to be a lack of knowledge of the circumstances for which it can be used. This is perplexing as the literature contains many examples of the ‘complex’ techniques applied to construction problems, demonstrating their applicability and thus there seems to be a problem in transferring this academic knowledge to practitioners.

All of the above studies indicate that there is a lack of knowledge of when to use a particular technique and that no one technique is available for every situation. The lack of a fully integrated decision support technique and the need for a formal framework has been identified in the literature (Dikmen *et al.* 2004; Wang *et al. 2004).*

Available techniques

The literature review identified 36 techniques applied to construction management problems. Some of these 36 exist at more than one of the risk management stages: this gives 16 for identification, 18 for estimation and 18 for evaluation. There are a further 13 techniques that only have one reference in the literature and insufficient details to assess problem characteristics. These have been omitted, and the 52 are used to develop the matrix.

The range of techniques is broad, and they have been grouped into the nine categories shown in Table 1.

Table 1: Risk management categories defined for the matrix

Identification	Estimation	Evaluation
Artificial Intelligence	Artificial Intelligence	Artificial Intelligence
Decomposition	Decomposition	Decomposition
Experiential	Experiential	
Failure ID	Failure ID	
	Other	Other
	Probabilistic	Probabilistic
Sensitivity analysis	Sensitivity analysis	Sensitivity analysis
Support Systems	Support Systems	Support Systems
Trees	Trees	Trees

PROBLEM BREAKDOWN STRUCTURE

To use the matrix, a universal breakdown structure is required. This must be rigorous and allow problems to be categorized. It must also be simple to use to allow selection of risk management techniques. This section outlines a two-stage process for this. The first stage examines the problem characteristics and the second the data.

Existing breakdown structures

There are a range of breakdown structures in the literature. The ‘risk environment’ breakdown divides between external and internal risks. External risks are those “arising from the external environment, not wholly within the organization’s control, but where action can be taken to mitigate the risk” (HM Treasury 2004). Conversely, internal risks are those within the organization’s control, or “risks that have their origin within the project organization or its host, arising from their rules, policies, processes, structures, actions, decisions, behaviours or cultures” (Barber 2005). This is a universal difference and is applicable to all types of risk; therefore, it is used as the highest level of breakdown. The difference between the external and internal nature is the position of the assessing organization. This high level of breakdown is too general for the purposes of selecting appropriate techniques; therefore, a further level of breakdown will be developed.

Stage A: the problem breakdown structure

To ensure that this process was rigorous a method for risk ranking was used (Morgan *et al*. 2000). This sets four objectives: (1) logical consistency; (2) administrative compatibility; (3) equitable; and (4) compatible with cognitive constraints and biases.

The requirements to meet each of these objectives are outlined by Morgan *et al*. (2000) and were all met in developing the Stage A structure.

The first step in developing Stage A was to assess existing generic structures. HM Treasury (2004) use the PESTLE Model to define the external risks associated with a project. PESTLE encompasses political, economic, socio-cultural, technological, legal and environmental aspects (Cabinet Office 2004). It was found that all of the external sources of risks in the literature could be mapped onto PESTLE. This was used for the breakdown of external risks.

The internal risks did not initially map to the PESTLE Model. To overcome this, internal risks identified in the literature (e.g. Edwards and Bowen 1998) were grouped and similarities identified. This forced categories to be created, developed and merged. From this it was possible to describe the internal risks using the PESTLE Model with minor refinements to the definitions.

There are two further parts of Stage A assessment. These are the ‘risk owner’ and the ‘project phase’. The risk owner determines the internal or external nature of a risk. The risk owner is defined as being contractor; client; consultant/designer; financier; facilities management organization or government. These were developed iteratively during the review of the literature. If other organizations had been identified (e.g. subcontractor, supplier), these would have been and can be included as necessary.

Many of the methods for identifying generic project stages were considered too detailed (RIBA 2000, Cooper *et al*. 2005). The stages used in the matrix were defined by reviewing examples in the risk management literature. These cover the whole life cycle of a project and are in line with the RIBA Plan of Work (2000) and whole life costing (Marenjak 2004). The stages are (1) inception/feasibility; (2) design; (3) construction; (4) commissioning; (5) operation; and (6) decommissioning.

Stage B: the data breakdown structure

To this point ,Stage A only defines the nature of the problem. No account is made for the characteristics of the data.

Two structures for uncertainty in construction data were identified. Kishk (2004) developed a framework for whole life cost data including tangibility, availability and randomness. Blockley (1995) included fuzziness, incompleteness and randomness (FIR). This is stated as being the basis of uncertainty in risk and reliability, and has been applied to systems in construction. The model is an established basis for uncertainty for construction systems (Blockley 1995; Blockley and Godfrey 2000). The FIR model was used as the base for the data characterization because it was generic and encompassed the breakdown of Kishk. Iterations were undertaken of the precise definition to ensure that the data in the risk problems are characterized. The definitions outlined below.

FIR model

The first element of the FIR model is fuzziness. Fuzziness is the imprecision of definition (Blockley 1995). For the purposes of defining the nature of data in a problem, fuzziness is present if that which is being assessed is imprecise. This imprecision may stem from a difference in understanding of the terms used, or from a range of possible values in the data itself. For example fuzziness may occur in terms such as high, medium or low; or large and small costs.

The incompleteness aspect of a model is concerned with that which is not known (Blockley and Godfrey 2000). Using this basis, all risk management models are attempting to model incompleteness. Thus, if the technique was being assessed on the ability to manage 'unknowns', all risk management techniques would fall into this category. In light of this, the exact nature of the incompleteness was refined to relate solely to the data that was applied in the model. This provided a better representation of the incompleteness of the data.

The final consideration is that of randomness. Randomness is the lack of a specific pattern in the information (Blockley 1995). This is the uncertainty defined by probability and statistics (Blockley and Godfrey 2000). This has been reviewed for each of the techniques by assessing data with no specific pattern.

Using the revised definitions of the FIR model, the data relating to a given problem could be characterized. This stage of characterization has been called Stage B.

Other considerations
The assessment attempted to include other measures. This was to ensure that all of the characteristics were defined. These included level of detail; consistency; chaotic behaviour and precision. However there are three reasons why the FIR model has been retained. (1) the model is simple to use and easily assessed; (2) the model is widely acknowledged in construction literature and was developed for uncertainty; and (3) the process of assessing examples in the literature demonstrated that data fitted the structure. Thus, the FIR model provides a representation of the data.

The final breakdown structure
The final breakdown structure is shown in Figure 1. This shows the two stages and the ways in which a problem is categorized. The four elements of Stage A and the FIR model of Stage B create a set of characteristics which allow a new problem to be compared to historical problems.

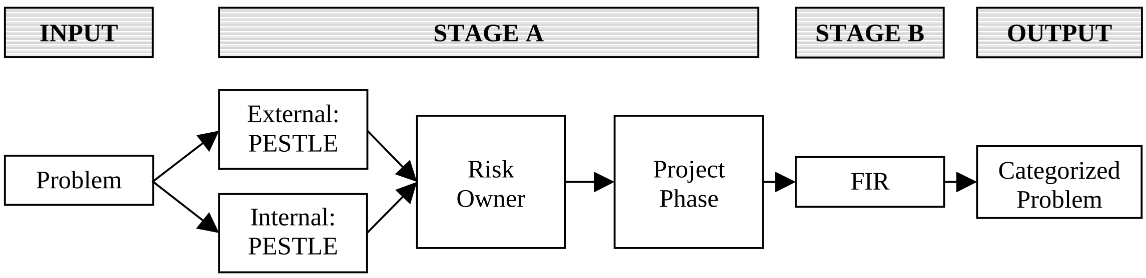


Figure 1: The problem breakdown stages

ANALYSIS OF TECHNIQUES

The historical problems were analysed against the breakdown structure above. Thus, a collection of problem characteristics and corresponding techniques was produced. In total, 179 examples were assessed, collected from 94 references.

During this process, it was noted that not all of the examples were actual applications. Some simply suggested a situation for which a technique should be applied. This was recorded as it was not considered that this should achieve the same merit as if an example were provided.

THE MATRIX

The matrix is two-dimensional, with the categorized problems on the horizontal axis and the techniques on the vertical. The matrix can be used as a decision support technique in selecting risk management techniques for a set of problem characteristics.

The matrix was constructed by assigning each technique to the problem situations it had been applied to. Where a technique was applied to more than one example, the characteristics were aggregated for each technique. This allowed all of types of problems for a given technique to be seen simultaneously. If there were 'suggested' and 'actual' examples, 'actual' took precedence.

There are two matrices: one covering Stage A and the other covering Stage B of the problem characterization. This is due to difficulties in consolidating and reconciling the stages arising from differing natures. This is not a problem, as it allows techniques to be selected on knowledge by either stage. If a technique is required for A&B, a check ensures that it complies with both. An extract of the matrix covering Stage A for identification techniques is given in Figure 2. Estimation and evaluation have been developed in a similar format.

DISCUSSION

The matrix produced is not only a useful tool, but also highlights trends and gaps within the risk management research. This section outlines these points and discusses ways of developing the matrix further.

The first aspect considered is the frequency with which techniques are applied in the matrix. There are 52 techniques available for all the risk management stages. The problem characteristic encompassed by most, both externally and internally, is economic. Forty different techniques have been used to manage internal economic risks. Twenty-nine have been applied to external economic risks. The reasons behind this probably stem from the ease of monetizing values to calculate the risk or the focus within the industry on profit and cost. Additionally, the large number of internal examples may be accounted for by organizations being concerned with the risks they can most readily control. External economic risks, including market and residual value, may be harder to assess and have therefore been avoided.

In the 'risk owner', there is a lack of technique examples that have been applied by government, financiers and facilities management organizations. In contrast, 32 of the techniques have been applied by contractors and 25 for, or on behalf, of clients. However, this may not be because the techniques are not applicable, but because an example has not been assessed covering that area. The relatively high number of examples for clients and designers can be attributed to the Construction (Design & Management) Regulations 1994 (CIRIA 2004a, 2004b). This put a larger onus on the designer and client to assess the risks.

In assessing Stage B, out of 52 techniques, 38 and 24 techniques can deal with incompleteness and randomness respectively; however, only 17 can deal with fuzziness. This is due to the relatively new emergence of fuzzy assessment and will probably increase as techniques grow in acceptance, and fuzzy methods are researched.

The missing values highlight the dynamic nature of the matrix. It has been constructed using 179 examples from the literature. A gap does not necessarily mean that a technique cannot be applied, but that an example has not been located to complete the matrix. However, as it stands the matrix allows valuable judgements to be made in selecting techniques.

Assessment Stage	Technique	External: Political	External: Economic	External: Social	External: Technological	External: Legal	External: Environmental	Internal: Political	Internal: Economic	Internal: Social	Internal: Technical	Internal: Legal	Internal: Environmental
Identification	Artificial Intelligence: Case Based Reasoning	S	S	S	S	S	S	S	S	S	S	S	S
	Decomposition: AHP	A	A	A	A	A	A	A	A	A	A	A	A
	Decomposition: Hierarchical Holographical Modelling (HHM)		A				A						
	Decomposition: Risk Breakdown Structure	A	A	A	A	A	A	A	A	A		A	A
	Decomposition: Soft Systems Methodology	A	A	A				A	A	A	A	A	A
	Experiential: Brainstorming	A	A	A	A	A	A	A	A	A	A	A	A
	Experiential: Checklists	S	A	A	S	S	S	S	A	A	A	A	A
	Failure Identification: Failure Modes & Effects Analysis (FMEA)										A	A	
	Failure Identification: HAZOP/HAZID				A	A					A	A	A
	Sensitivity Analysis: Breakeven Analysis		A						A		A		
	Sensitivity Analysis: Scenario Analysis		S										
	Support Systems: Nominal Group	S	S	S	S	S	S	S	S	S	S	S	S
	Trees: Decision/Influence Trees								A		A		
	Trees: Event Trees						A				A		
	Trees: Fault Trees								A		A	A	A
	Trees: Means end chain								A		A		

Technique	Inception/Feasibility	Scheme Design	Construction	Commissioning	Operation	Decommissioning	Stage Non Specific
Artificial Intelligence: Case Based Reasoning							S
Decomposition: AHP			A				
Decomposition: Hierarchical Holographical Modelling (HHM)							A
Decomposition: Risk Breakdown Structure		A					
Decomposition: Soft Systems Methodology		A	A	A	A		
Experiential: Brainstorming	A	A	A	S	S	S	A
Experiential: Checklists	S	S	S	S	S	S	A
Failure Identification: Failure Modes & Effects Analysis (FMEA)		A	A		A		
Failure Identification: HAZOP/HAZID		A	A		A		
Sensitivity Analysis: Breakeven Analysis	A						
Sensitivity Analysis: Scenario Analysis			S		S		
Support Systems: Nominal Group							S
Trees: Decision/Influence Trees	A	A	A				
Trees: Event Trees					A		
Trees: Fault Trees			A		A		
Trees: Means end chain							A

Technique	Client	Contractor	Consultant/Designer	Financier	Facilities Manager	Government	Owner Non Specific
Artificial Intelligence: Case Based Reasoning							S
Decomposition: AHP		A					
Decomposition: Hierarchical Holographical Modelling (HHM)							A
Decomposition: Risk Breakdown Structure		A					
Decomposition: Soft Systems Methodology		A		A	A		
Experiential: Brainstorming	A	A	S	S	A	A	A
Experiential: Checklists	A	A	S	S	S	S	S
Failure Identification: Failure Modes & Effects Analysis (FMEA)	A	A	A				
Failure Identification: HAZOP/HAZID	A	A	A				
Sensitivity Analysis: Breakeven Analysis	A						
Sensitivity Analysis: Scenario Analysis		S		S	S		
Support Systems: Nominal Group							S
Trees: Decision/Influence Trees	A	A	A	A			
Trees: Event Trees	A		A				
Trees: Fault Trees	A	A			A		A
Trees: Means end chain		A					

Key:

A	Actual Example of Tool
S	Suggested Example of Tool

Figure 2: Extract from Stage A of risk management matrix showing identification techniques

Several points relating to the technique groups can be extracted from the matrix:

- Techniques that belong to the tree group, failure identification and sensitivity analysis do not tend to be suited to assessing external risks.
- The support system group does not tend to have examples detailing the owner or phase of the work.
- There is a lack of techniques to evaluate internal political risks. This is true, although to a lesser extent, for internal political and legal risks.
- Fuzzy logic is the most commonly used artificially intelligent technique. The use of neural networks is limited to internal economic risks, and case-based reasoning is 'suggested' as being universally applicable.
- Experiential estimation techniques tend to be non specific regarding the risk owner.

Two major pitfalls can be seen in the matrix. Firstly, no account is made for the frequency with which a technique has been applied in the past. A decision on technique selection has to be made on whether the problem characteristics exist. There is no indication if this is once or several times. For the matrix to be of more use, a means of overcoming this should be addressed.

The second issue is that the position of the risk owner is clouded by the aggregation. It is no longer clear which external and internal risks are associated with a given owner, thus confusion may occur in selecting the appropriate tool.

Further work

One limitation of the matrix is that it can be difficult to use in selecting appropriate risk management tools. To overcome this, options of 3-D and triangular matrices have been considered. However, these were either unworkable or overly complex. A methodology that is designed to use historic examples to make decisions is case-based reasoning (CBR). It is proposed to develop a CBR model based on the data set used in this study. This will make it easier to select appropriate techniques.

It is also suggested that CBR will allow assessments to be made on the past frequency technique examples. This CBR model would also be able to relate the risk owner to each of the internal and external positions, which would overcome the problems caused by the aggregation in the matrix.

CONCLUSIONS

The risk management technique matrix that has been produced from this work is a useful tool in selecting the most appropriate risk management techniques for the built environment. This overcomes the issue of knowing when particular technique can be applied. However, it is still necessary for the user of the technique to gain an understanding of the technique's methodology.

The data structure is constrained by using a standard breakdown. However, it is important that this has a combination of simplicity, while remaining comprehensive. Additional measures beyond the FIR were considered and were found to be difficult to quantify and assess. FIR has been used because it is well established, takes a generic approach to representing uncertainty and is easily understood.

The matrix output has shown that there is a lack of tools available to deal with particular areas. These were the 'softer' risks in: (1) external – technological, legal and political; and (2) internal – political and social. Further research could be carried out into these areas, including the development of fuzzy techniques and the application of techniques for government, financiers and facilities management organizations. A more complete and accurate database could then be established from which to build the matrix.

REFERENCES

Akintoye, A S and MacLeod, M J (1997) Risk Analysis and Management in Construction. *International Journal of Project Management*, **15**(1), 31–8.

Bajaj, D, Oluwoye, J and Lenard, D (1997) An analysis of contractors' approaches to risk identification in New South Wales, Australia. *Construction Management and Economics*, **15**(4), 363–9.

Baker, S, Ponniah, D and Smith, S (1999) Risk response techniques employed for major projects. *Construction Management and Economics*, **17**(2), 205–13.

Barber, R B (2005) Understanding internally generated risks in projects. *International Journal of Project Management*, **23**(8), 584–90.

Blockley, D (1995) Process Re-engineering for Safety. *In:* M James (Ed.) *Risk management in civil, mechanical and structural engineering*, 22 February, London, 51–66.

Blockley, D and Godfrey, P (2000) *Doing It Differently: Systems for Rethinking Construction*. London: Thomas Telford Ltd.

Cabinet Office (2004) Strategy Survival Guide. Available online: http://www.strategy.gov.uk/downloads/survivalguide/downloads/ssg_v2.1.pdf (accessed May 2006).

CIRIA (2004a) *CDM Regulations – practical guidance for clients and clients' agents*. London: CIRIA.

CIRIA (2004b) *CDM Regulations – work sector guidance for designers*. London: CIRIA.

Cooper, R, Aouad, G, Lee, A, Wu, S, Fleming, A and Kagioglou, M (2005) *Process Management in Design and Construction*. Oxford: Blackwell.

Dikmen, I, Birgonul, M T and Arikan, A E (2004) A Critical Review of Risk Management Support Tools. *In: 20th Annual Conference of Association of Researchers in Construction Management (ARCOM)*, 1–3 September, Heriot Watt University, Edinburgh, **1**, 1145–54.

Edwards, P J and Bowen, P A (1998) Risk and Risk Management in construction: a review and future directions for research. *Engineering, Construction and Architectural Management*, **5**(4), 339–49.

Flanagan, R and Norman, G (1993) *Risk Management and Construction*. Oxford: Blackwell.

Hillson, D (2002) What is Risk? Towards a Common Definition. *InfoRM Magazine: Journal of the UK Institute of Risk Management*, **April**, 11–12.

HM Treasury (2004) *The Orange Book. Management of Risk – Principles and Concepts*. Norwich: HMSO.

Jaafari, A (2001) Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management*, **19**(2), 89–101.

Kaplan, S, Haimes, Y Y and Garrick, B J (2001) Fitting Hierarchical Holographic Modeling into the Theory of Scenario Structuring and a Resulting Refinement to the Quantitative Definition of Risk. *Risk Analysis*, **21**(5), 807–20.

Kishk, M (2004) Combining various facets of uncertainty in whole-life cost modelling. *Construction Management and Economics*, **22**(4), 429–35.

Marenjak, S (2004) *A generic approach to minimising WLC in the building industry*, PhD Thesis, University of Dundee.

Morgan, M G, Florig, H K, DeKay, M L and Fischbeck, P (2000) Categorizing Risks for Risk Ranking. *Risk Analysis*, **20**(1), 49–58.

Pate-Cornell, E (2002) Finding and Fixing Systems Weaknesses: Probabilistic Methods and Applications of Engineering Risk Analysis. *Risk Analysis*, **22**(2), 319–34.

Perry, J G and Hayes, R W (1985) Risk and its management in construction projects. *Proceedings of the Institution of Civil Engineers*, **78**(1), 499–521.

RIBA (2000) *Plan of Work*. London: RIBA Enterprises.

Wang, J, Sii, H S, Yang, J B, Pillay, A, Yu, D, Liu, J, Maistralis, E and Saajedi, A (2004) Use of Advances in Technology for Maritime Risk Assessment. *Risk Analysis*, **24**(4), 1041–63.

Wood, G D and Ellis, R C T (2003) Risk management practices of leading UK cost consultants. *Engineering, Construction and Architectural Management*, **10**(4), 254–62.

ANALYTICAL TOOL FOR CHOOSING BRIDGE REHABILITATION STRATEGY

Saleh Abu Dabous[1], Sabbah Alkass[1] and Adel Zaki[2]

[1]*Dept. of Building, Civil & Environmental Engineering, Concordia University, 1515 St. Catherine West. Rm.: EV-6.139, Montréal, Québec, Canada, H3G 2W1*
[2]*SNC-Lavalin Inc., 455 René-Lévesque Blvd. West, Montréal, Québec, Canada, H2Z 1Z3*

Bridge management is the decision-making process for selecting and prioritizing actions necessary to maintain a bridge network within acceptable limits without exceeding budget constraints. Decision support systems can help engineers and practitioners in making effective decisions through: (1) improved identification and information of the infrastructure assets; (2) methodologies for needs assessment; and (3) analytical tools for evaluation of alternative solutions. This paper describes a research to choose a decision making technique for an under development bridge deck decision support system. Four quantitative multiple criteria decision making techniques are evaluated. From these, the Analytic Hierarchy Process (AHP) is selected to develop an analytical framework to evaluate and rank alternative bridge rehabilitation strategies. The AHP provides an effective analytical tool to deal with complex decision making and has the following qualities: (1) multi-criteria decision making process; (2) utilize both actual measurements and expert judgment in the decision making process; and (3) the process has a special concern with consistency of judgement and it deals with the departure from consistency.

Keywords: AHP, bridge, decision, rehabilitation.

INTRODUCTION

Aging civil infrastructure has become a major social and economical concern in North America. The concern is due to the fact that satisfactory performance of existing civil infrastructure is essential to maintain economic growth and social development of a modern society. Civil infrastructure facilities and related services can be categorized in groups based on their primary functions and services. The transportation system is one major group of the infrastructure system and includes ground, air, waterways and mass transportation (Hudson *et al*. 1998).

In particular, bridges are important item of the transportation system. Bridges are the most vulnerable element because of their distinct function of joining highways as crucial nodes. In addition, bridges are exposed to aggressive environment and increasing traffic volumes and truck loads (Frangopol and Liu 2005).

Deterioration is a major problem in the operation of a nation's highway bridges. Maintaining, repairing and replacing (MR&R) deteriorating bridges are among the most expensive items for highway agencies.

Managers of municipal infrastructure realize the need for effective tools to manage the vast asset base, and are now demanding decision-support tools to help them in their

[1] saleh_ab@alcor.concordia.ca

work (Vanier 2000). In particular, it is essential to develop rational tools to aid bridge managers in the decision making process.

BRIDGE MANAGEMENT DECISION MAKING

Many bridge management systems currently used base their decision making process on optimizing life cycle cost while enforcing relevant performance constraints. Pontis and Bridgit, among the widely used bridge management systems in the United States, have adopted this methodology (Thompson *et al*. 1998; Hawk and Small 1998). For instance, Pontis utilize dynamic programming to find the optimal long-term policy that minimizes expected life cycle costs while keeping the element out of risk of failure (Thompson *et al*. 1998).

Practical difficulties exist when applying the optimized life cycle cost methodology (Frangopol and Liu 2005). These difficulties arise when the available budget are larger or lower than the minimum life cycle cost. If the available budgets are larger than the computed minimum life cycle cost, the bridge performance can be maintained at a higher level than the level maintained at minimum life cycle cost solution. If the financial resources are not enough to meet the computed minimum life cycle cost, bridge managers have to look for another solution that can improve bridge performance to the highest possible level with the available budget. In addition, more criteria beside cost can participate in the decision making process. Decisions can be governed by multiple criteria and constraints that require the decision maker's knowledge, experience and judgment.

Decision making criteria can evolve in a subjective manner. An example on that is the user cost that is different than the agency cost. The user cost during bridge MR&R projects has several sources and can be either due to delay while the user is using alternative routes or due to accidents while closing the bridge. This cost is not easily estimated in and can evolve in subjective manner to be high for certain MR&R action, medium or low for others.

MULTIPLE-CRITERIA DECISION MAKING

Multiple-criteria decision making is a complex process that requires expert knowledge and judgment to rank and prioritize alternatives. In addition to ranking and prioritizing, the decision making process addresses several issues including clarifying purpose, evaluating alternatives, assessing risks and benefits.

Decision analysis techniques are rational procedures to utilize information, data, and experience in order to facilitate the decision making process in a systematic way. These techniques can aid in the decision making process but are not intended to replace decision makers.

Several decision making techniques have been developed and used in a variety of applications. Few of these techniques are simple qualitative procedures to evaluate the advantages and disadvantages of each alternative and rank the alternatives accordingly. Other techniques are quantitative systematic procedures to utilize data and experience to rank and prioritize a group of alternatives.

Four quantitative decision making techniques proposed in the literature are evaluated in this paper for use in bridge management decision making. These techniques are Analytic Hierarchy Process (AHP), Multi-Attribute Utility Theory (MAUT), Cost Benefit Analysis (C/B) and Kepner-Tregoe Decision Analysis (K-T). Barker *et al*.

(2001) presented comprehensive discussion of these techniques. Table 1 defines the concepts of these techniques.

Table 1: Decision making techniques

Technique	Description
MAUT	Combine dissimilar measures of costs, risks, and benefits, along with individual and stakeholder preferences, into high-level, aggregated preferences
C/B Ratio	Discounting benefits and costs to transform gains and losses occurring in different time periods to a common unit of measurement
K-T	Team of experts numerically scores criteria and alternatives based on individual judgments and assessments
AHP	Pair-wise comparisons of alternatives based on their relative performance against the criteria

The four decision making techniques can be used in bridge management decision making. Table 2 presents advantages and disadvantages associated with each of the four techniques. The AHP is found to have the most advantages and limited disadvantage that can be accounted for. The disadvantage of AHP is the large size of the developed matrices. This can be accounted for by developing computer software to facilitate handling large size matrices.

ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is a general theory of measurements developed by Thomas Saaty (1980). The theory presented in this section is based on decision making dependence and feedback authored by Saaty (2001). The AHP provides an effective analytical tool to deal with complex decision making. It is a multi-criteria decision process that utilizes both actual measurements and expert judgment. It has a special concern with departure from consistency and the measurement of this departure.

Two fundamental steps are required to use the AHP methodology. First, a complex system is broken into a hierarchic structure to represent the problem. Second, pairwise comparisons are performed to measure the relative impact of different elements in the hierarchy and to establish relations within the structure.

Fundamental scale of absolute values for representing the strength of judgments has been developed and validated (Saaty 1980, 2001). In this approach, the decision maker expresses his/her opinion about the value of one single pairwise comparison at a time. Usually, the decision maker has to choose an answer among discrete choices. Table 3 presents the scale of relative importance.

The pairwise comparisons lead to dominance matrices from which ratio scales are derived in the form of principal eigenvectors. These matrices are positive and their elements are reciprocal. Thus for any element a_{ij}, the value of elements $a_{ji} = 1/a_{ij}$.

Finally, the judgments are synthesized to determine the overall priorities of the variables and the criteria.

Table 2: Decision making techniques advantages and disadvantages

Technique	Advantages	Disadvantages
MAUT	-Suitable for complex decisions with multiple criteria and many alternatives. -Additional alternatives can be readily added to a MAUT analysis	- Data or judgment must be available to develop the utility functions
C/B Ratio	- Useful to define desirability of government projects or policies	-Suitable only when decision making is based on the monetary cost vs. monetary benefit of the alternatives
K-T	-Simple and requires only basic arithmetic	-Suitable for moderately complex decisions involving few criteria -The scoring system is not well-defined. For example it is that it is not clear how much score “7” is better than score “6” -Scores may be close together, making a clear choice difficult
AHP	-AHP is a useful when there are multiple criteria -AHP is suitable for decisions with both quantitative and qualitative criteria -Break down complex problems into hierarchy structure that provides a structured model of the problem - Facilitate decision making by allowing relative judgment - Define functional utilities based on simple comparisons and provide consistent, meaningful results	- If high number of alternatives and criteria are considered, the number of pairwise comparisons is high. This may foster carelessness among decision makers while performing the pairwise comparisons.

Table 3: Scale of relative importance (Saaty 2001)

Intensity	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

AHP METHODOLOGY FOR CHOOSING BRIDGE REHABILITATION STRATEGY

As stated earlier, choosing a rehabilitation strategy can be governed by a group of subjective criteria. AHP methodology can aid decision makers with this task. The AHP methodology application to choose an appropriate rehabilitation action is summarized in the following steps.

Identify alternatives and decision criteria and decompose the problem into a hierarchy

Decision makers can choose a group of rehabilitation strategies R_i (i = 1,2,.....,n) to evaluate for a specific projects. A best strategy is the strategy that meets the multiple criteria established by the decision maker. The criteria are denoted by C_j (j = 1,2…..,m).

Three levels hierarchy structure can be identified. The first level represents the overall objective of choosing best strategy. The second level represents criteria that contribute to the overall goal. The third level represents the candidate alternatives to be evaluated in terms of the criteria on the second level. In this case, the candidates are the rehabilitation strategies. Figure 1 represents the decomposition of the problem into a hierarchy.

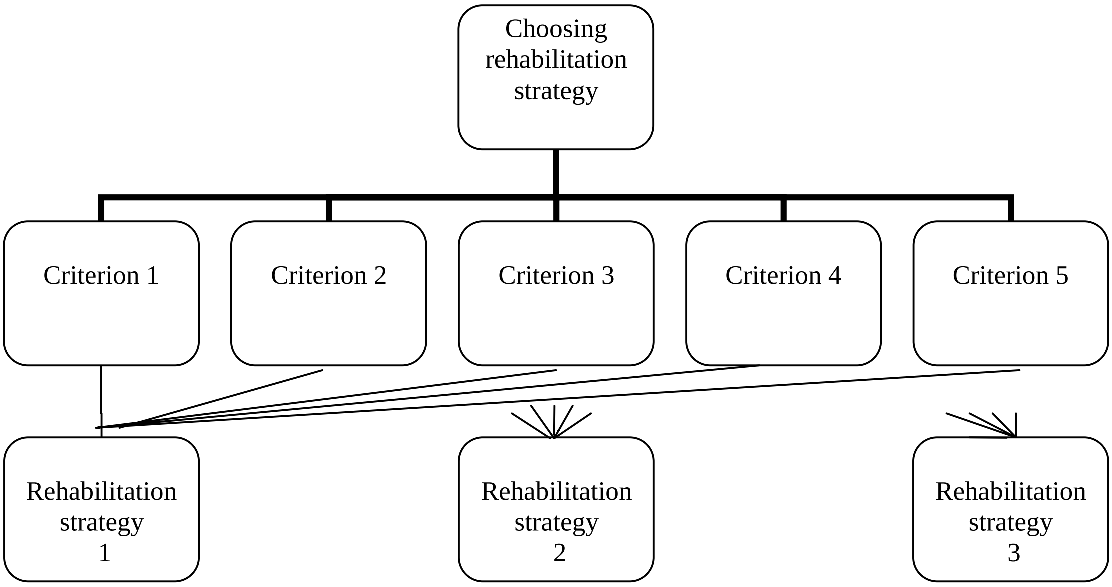


Figure 1: Hierarchy structure for ranking bridge rehabilitation strategies

Perform comparative judgment

At the middle level, a matrix of comparison in the order of (m × m) is derived to relate the relative preferences of the different criteria. This preference is elicited from the expert judgments about the relative importance of the criteria with respect to the overall goal of choosing best rehabilitation strategy. Every two criteria are compared by asking which one is considered more important and how much more important with respect to the overall goal. Scale of relative importance presented in Table 3 is used to give the numeric weights for the linguistic expressions of judgment. If elements in the matrix of comparison satisfy the conditions of $a_{ij} = 1/a_{ji}$ and $a_{ii} = 1$ for all i, then the matrix is a reciprocal one.

$$CM = \begin{bmatrix} 1 & S_{1,2} & S_{1,3} .... S_{1,m} \\ \frac{1}{S_{1,2}} & 1 & S_{2,3} .... S_{2,m} \\ \frac{1}{S_{1,3}} & \frac{1}{S_{2,3}} & 1 .... S_{4,m} \\ . & . & . ... \\ . & . & .... \\ . & . & .... \\ \frac{1}{S_{1,m}} & \frac{1}{S_{2,m}} & .... 1 \end{bmatrix}$$

At the bottom level, pairwise comparisons between different strategies with respect to each criterion are performed. For each criterion, a matrix in the order of (n × n) is developed to represent the relative preference of the different rehabilitation strategies with respect to that particular criterion.

Determine vector of priorities

Vector of priorities is a normalized eigenvector. In absence of large-scale computers to solve the problem, an alternative crude estimate can be used to yield an acceptable approximation for the vector of priorities.

The vector of priorities is estimated in two steps. First, normalize the developed matrices. This is done by computing the sum of each column and dividing each element in a column by the sum of that column. Second, compute the average of each row. The average value of each row represents the priority weight of the corresponding element or criterion.

Determine the eigenvalue and consistency ratio.

One feature of the AHP methodology is checking for consistency. The process allows inconsistency in the pairwise comparisons to a certain extent. If all the comparisons are perfectly consistent, then $w_{ij} = w_{ik}\ w_{kj}$ should always be true for any combination of comparisons taken from the judgment matrices.

A consistency index (CI) can be determined for this purpose. Small value of the CI represents small deviation from consistency which reflects an acceptable consistent judgment.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

where λ_{max} is an approximation of the maximum eigenvalue. A simple way to obtain λ_{max} is by adding the elements in each column in the judgment matrix and multiplying the resulting vector by the vector of priorities (i.e. the approximated eigenvector) obtained earlier.

In AHP, the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10% (Saaty 1980). CR is equal to CI/RI where RI is a random consistency index derived from a large sample of randomly generated reciprocal matrices. Table 4 represents values of RI for different matrix size.

A small consistency ratio less than 10% reflects an informed judgment that could be attributed to expert knowledge about the problem under study. If this limit is not achieved, the expert is required to revise the pairwise comparisons to improve consistency.

Table 4: Random index values for different number of elements matrix (Saaty 2001)

Number of elements (n)	R.I.
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49
11	1.51
12	1.54
13	1.56
14	1.57
15	1.58

Synthesize the priorities

Finally, compose global priorities of the different rehabilitation strategies. Lay out local priorities of each strategy with respect to each criterion. Multiply each weight in the resulting vector by the corresponding criterion weight and add across each row to find the overall weight. The resulted vector is the global priority vector of all strategies. The different strategies are ranked according to their overall weights and a strategy with the highest weight represents preferred rehabilitation strategy.

HYPOTHETICAL EXAMPLE

The following is a hypothetical example to demonstrate the AHP as a tool to choose bridge deck rehabilitation strategy. A deteriorating bridge deck is expected to reach the intervention level next year. The decision maker is required to evaluate alternative rehabilitation strategies. The assessment and pairwise comparisons in this example are performed by the authors.

The available strategies are major rehabilitation, minor rehabilitation or increased routine maintenance. These three alternatives should be evaluated using the following criteria: agency cost, user cost, bridge safety, bridge deck useful life and environmental impact.

Figure 2 presents the decomposition of the problem into a hierarchy. The first level is the overall goal of choosing a rehabilitation strategy. The second level represents the five criteria that contribute to the overall goal, and the third level represents the three candidate rehabilitation strategies.

The pairwise judgment matrices shown in Tables 5 and 6 are developed using the authors’ judgment and based on the scale of relative importance presented in Table 3. The matrix in Table 5 is obtained by comparing the set of criteria in pairs with respect to the overall goal. The matrices in Table 6 are obtained by comparing the alternative rehabilitation strategies in pairs with respect to each criterion.

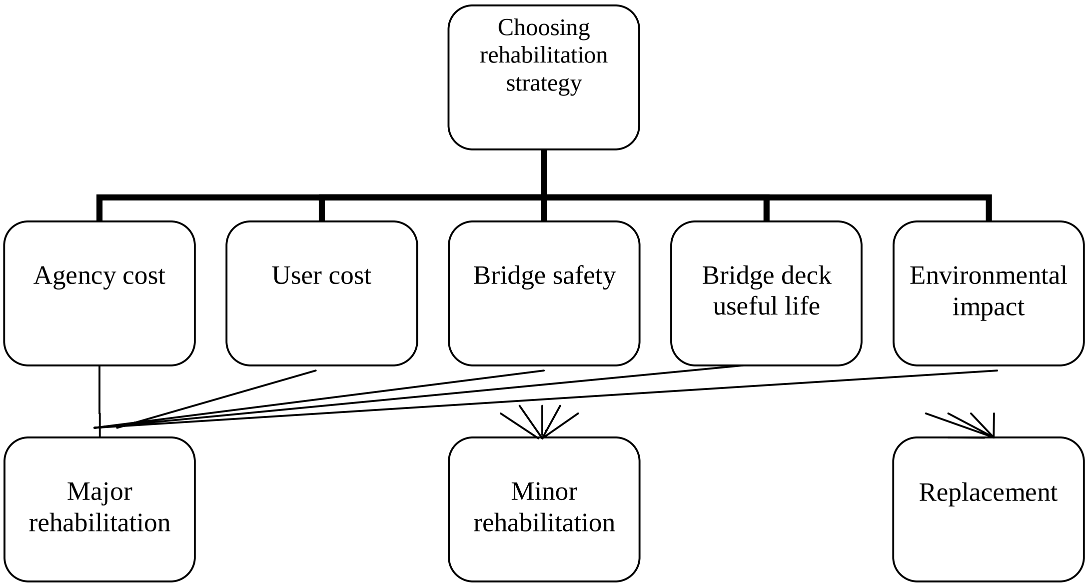


Figure 2: Hierarchy structure for choosing bridge rehabilitation action

Table 5: Comparison of criteria with respect to the overall goal

Criteria	Agency cost	User cost	Bridge safety	Useful life	Environmental impact	Priority vector
Agency cost	1	2	1/6	1	1	0.121
User cost	1/2	1	1/3	1/2	1/2	0.088
Bridge safety	6	3	1	6	6	0.548
Useful life	1	2	1/6	1	1	0.121
Environmental	1	2	1/6	1	1	0.121

λ_{max} = 5.342, C.I. = 0.085, R.I. = 1.11, C.R. = 0.076

Estimated consistency ratios for the judgment matrices are less than 10% which reflect an informed consistent judgment.

Finally, global priorities of the different rehabilitation actions are as follow:

Major rehabilitation = 0.58

Minor rehabilitation = 0.28

Increased routine maintenance = 0.24

The analysis prefers a major rehabilitation and gives approximately the same weight for minor rehabilitation and increased routine maintenance.

Table 6: Comparison of alternatives with respect to each criterion

Agency Cost	Major	Minor	Routine	**Priority**
Major	1	1/3	1/6	0.093
Minor	3	1	1/4	0.221
Routine	6	4	1	0.685

λ_{max} = 3.085, C.I. = 0.042, C.R. = 0.081

User Cost	**Major**	**Minor**	**Routine**	**Priority**
Major	1	1/ 4	1/ 6	0.089
Minor	4	1	1/2	0.323
Routine	6	2	1	0.587

λ_{max} = 3.012, C.I. = 0.006, C.R. = 0.011

	Environmental Major Minor Routine	Priority
Major	1 2 4	0.571
Minor	1/2 1 2	0.286
Routine	1/4 1/2 1	0.143

λ_{max} = 3, C.I. = 0, C.R. = 0

	Bridge Safety Major Minor Routine	Priority
Major	1 2 4	0.571
Minor	1/2 1 2	0.286
Routine	1/4 1/2 1	0.143

λ_{max} = 3, C.I. = 0, C.R. = 0

	Useful Life Major Minor Routine	Priority
Major	1 3 8	0.669
Minor	1/3 1 4	0.257
Routine	1/8 1/4 1	0.074

λ_{max} = 3.028, C.I. = 0.014, C.R. = 0.026

CONCLUSION

This paper reviews bridge management decision making regarding maintenance and rehabilitation. In addition, it discusses four quantitative decision making techniques that can be used for bridge rehabilitation decision making. The AHP methodology is further discussed for its suitability for this purpose. A hypothetical example is presented to demonstrate the use of AHP to choose bridge deck rehabilitation strategy.

The AHP is a valuable tool for evaluating alternatives using multiple criteria while incorporating expert judgment. It facilitates complex decisions and makes them intuitive and rational.

The process benefits from the various advantages of using hierarchy structures and establishes the weights of attributes in a systematic and robust manner. The hierarchy structures' advantages include the following: (1) they describe how changes in upper levels affect elements in the lower level; (2) hierarchy structures assemble natural systems more efficiently than assembling systems as a whole; and (3) they are flexible allowing for adding new elements without disturbing the performance.

One important advantage of the AHP for the selection bridge rehabilitation strategy lies in its capacity to enable the process of rank reversal. Rank reversal involves a change in rank among a list of ranked alternatives, when a new alternative is added or deleted. This feature is the strength of the AHP since rank reversals do occur in practice. For example, if a high-quality rehabilitation strategy is added to the list of alternatives, rank reversal should take place to prioritize the new attractive alternative.

Another advantage is that the AHP allows the decision maker to check the consistency of the judgment regarding the relative importance among the involved criteria and among the alternatives. The decision maker can revise the relative importance to enhance the consistency and perform more informed judgment.

The AHP is normally based on expert judgment. The process might be associated with difficulties if large number of alternative and criteria are involved. Performing many pairwise comparisons may foster carelessness among the decision makers while doing the comparisons. In addition, reviewing large size matrices to enhance consistency can be a difficult task. However, for the purposes of choosing a bridge rehabilitation strategy, the alternatives and criteria involved are limited and the decision makers will not face this problem

For the features discussed above, the AHP has been adopted as a decision making process for a bridge deck decision support system under development.

REFERENCES

Baker, D, Bridges, D, Hunter, R, Johnson, G, Krupa, J, Murphy, J and Sorenson, K (2001) *Guidebook to Decision Making Methods*. Report Developed for the Department of Energy in USA.

Frangopol, D and Liu, M (2005) Bridge management based on multiple-objective optimization. *In: Proceedings of the 5th International Conference on Bridge Management, Bridge Management 5: Inspection, Maintenance, Assessment and Repair,* 2005, 235–42.

Hawk, H and Small, P (1998) The BRIDGIT Bridge Management System. *Structural Engineering International,* **8**(4), 309–14.

Hudson, R, Haas, R and Uddin, W (1998) *Infrastructure management.* New York: McGraw-Hill.

Saaty, T (1980) *The Analytic Hierarchy Process.* New York: McGraw-Hill.

Saaty, T (2001) *Decision Making with Dependence and Feedback: The Analytic Network Process*. Pittsburgh: RWS Publications.

Thompson, P, Small, E, Johnson, M and Marshall, A (1998) The Pontis Bridge Management System. *Structural Engineering International,* **8**(4), 303–8.

Vanier, D (2000) Advanced Asset Management: Tools and Techniques. *In: Innovations in Urban Infrastructure Seminar of the APWA International Public Work Congress,* Louisville, USA, 39–57.

IDENTIFICATION OF KEY PERFORMANCE INDICATORS TO ESTABLISH THE VALUE OF 4D PLANNING IN UK CONSTRUCTION INDUSTRY

Nashwan Dawood[1] and Sushant Sikka

Centre for Construction Innovation and Research, School of Science and Technology, University of Teesside, Middlesbrough, TS1 3BA, UK

Performance measurement has received considerable attention by both academic researchers and industry over a past number of years. Researchers have considered time, cost and quality as the predominant criteria for measuring project performance. In response to the Latham and Egan reports to improve the performance of construction processes, the UK construction industry has identified a set of non-financial Key Performance Indicators (KPIs). A literature review reveals that a standard measurement framework to evaluate the value of Information Technology (IT) both at quantitative and qualitative levels does not exist. Following an increased utilization of IT-based technology in the construction industry and in particular 4D (3D+time) planning, there is a great need to evaluate the value of such tools in the construction industry. There is great need to develop IT-based KPIs to promote its value. The aim of this ongoing research is to develop a suitable measurement framework to identify and analyse key performance indicators for 4D applications. Two major issues have been addressed in this research: an absence of a standardized set of 4D-based KPIs and lack of existing data for performance evaluation. This paper reports on the first stage of the research study carried out to identify the 4D performance measures on the basis of semi-structured interviews and questionnaire.

Keywords: 4D planning, information technology, scheduling, value, visualization.

INTRODUCTION

Applications of Information Technologies (IT) are progressing at a pace and their influence on working practice can be noticed in almost every aspect of the industry. The potential of IT applications is significant in terms of improving organization performance, management practices, communication and overall productivity. The evaluation and justification of investment in IT infrastructure and tools is crucial to rationalize the high capital cost involved in it. The thrust for improved construction planning efficiency and visualization methodology has resulted into the development of 4D planning.

4D is a planning process to link the construction activities represented in programmes with 3D CAD data to develop a real-time graphical simulation of planned construction schedules. In current practice, a planner has to first interpret what has to be constructed on the basis of available information (design documents, 2D CAD drawings and 3D model). Planner then identifies a list of activities required to construct the project. Finally, on the basis of construction method and based on available resources, the planner creates sequential relationship among the activities

[1] n.n.dawood@tees.ac.uk

and calculates activity and project duration to generate schedule. The traditional planning approach does not assist planners to consider the constructability issues during the advanced development of schedules. As a result, such issues are left for later decisions on the site. In 4D planning, project participants can effectively visualize, analyse and communicate problems regarding sequential, spatial and temporal aspects of construction schedules, and thereby rehearse construction progress in 3D at any time during the construction process. Consequently, much more robust schedules can be generated to reduce rework and improve productivity. According to Dawood *et al.* (2002), 4D planning allows participants in the project to effectively visualize and analyse the problems since the sequencing of space and temporal aspects of the project are considered by visualizing and communicating the project schedule. The industry based Key Performance Indicators (KPIs) that have been developed by the Department of Trade and Industry (DTI) sponsored construction best practice program (CBPP) are too generic and do not reflect the value of deploying IT system for construction planning and in particularly 4D planning. The key objective of this research study is to overcome the presence of a generalized set of KPIs by developing a set of 4D-based KPIs at a project level and in particular site operations.

A major research work was carried out by Construction Industry Institute (CII) to investigate the use of three-dimensional computer models in the industrial process and commercial power sector of AEC (architectural, engineering and construction) from 1993 to 1995 (Griffis *et al.* 1995). The study of CII concluded that the application of 3D computer model has the potential to reduce interference problems, improve visualization, reduce rework, enhancement in engineering accuracy and improve jobsite communications. Songer (1998) carried out a study to demonstrate the use of 3D CAD technology during the project planning phase. The study focuses on the impact of using 2D and 3D technologies in the project schedule review. Songer's experimental results demonstrated that the use of 3D-CAD technologies during planning stage on a construction project could assist in enhancing the scheduling process by reducing the number of missing activities and relationships between various activities as well as invalid relationships in the schedule and resource fluctuations for complex construction processes.

The Centre for Integrated Facility Engineering (CIFE) at Stanford University has demonstrated and reported the benefits of 3D and 4D modelling using various case study approaches (Koo and Fischer 1998; Haymaker and Fischer 2001; Staub-French and Fischer 2001). The application of the Product Model and Fourth Dimension (PM4D) approach at Helsinki University of Technology Auditorium Hall 600 (HUT-600) project in Finland has also demonstrated the benefits of 4D modelling approach in achieving higher efficiency; better design quality and the early generation of a reliable budget on the project (Kam *et al*. 2003).

Various research efforts had been undertaken in an attempt to capture current construction planning techniques. Researcher (Songer *et al*. 2001; Messner and Horman 2003; Haymaker and Fischer 2001) evaluated the effectiveness of computer visualization (4D CAD) to demonstrate the potential of 4D CAD visualization techniques compared to traditional planning approaches during the planning review process. The whole basis of using 4D planning is to identify logical and effective sequencing of the construction activities in construction projects prior to its execution. A rehearsal of the construction processes over time will identify and assist in overcoming spatial and resource conflicts for example, workspace conflicts, constructability, workflow etc., which cannot be represented by using conventional planning techniques. The above studies lack a well-established performance metrics that would allow the quantification of 4D planning at site process level. In the absence of well-defined measures at site process level, the priority of this research project is to establish a set of key performance indicators that will reflect the influence of 4D applications. This will assist in justification of investment in 4D planning in the industry. The remainder of the paper discusses the research methodology adopted for selection of 4D KPIs, ranking of KPIs, statistical analysis and findings of interviews.

RESEARCH METHODOLOGY

The ultimate objective of this research is to deliver project based 4D performance measures and to identify whether project performance can be improved by the utilization of 4D planning. This research has followed a well-defined methodology for the identification of 4D-based key performance indicators (KPIs). The methodology compromises of following three interrelated phases:

1. Identification of performance measures (4D perspective) through literature review.
2. Collection and analysis of interview survey data from various stakeholders (client, construction managers, general contractors, project managers and planners) viewpoint who are involved in the construction project.
3. Quantifying the performance measures for three construction projects.

This paper focuses on the process of identification and development of 4D performance measures by considering the above two phases of the research methodology (i.e. I & II).

Identification and selection of KPIs

The first step in the development of the KPIs was to identify the performance measures that can be utilized for performance assessment later. This was done by the development of a performance measure list that has considered the performance measure characterized by Rethinking Construction, the construction best practice program that launched industry wide KPIs for measuring the performance of construction companies (CBPP-KPI 2004). The Construction Best Practice Program identified a framework for establishing a comprehensive measurement system within both the organization and project level. Other literature includes Kaplan and Norton (1992), Li *et al*. (2000); Chan *et al*. (2002), Cox *et al*. (2003), Albert and Ada (2004), Bassioni *et al*. (2004) were used for the identification of performance measures.

A questionnaire was designed to confirm the performance measure that can be used to validate the value of 4D planning. The reason behind the development of questionnaire was to collect the specific information on identification of 4D performance measures, how to collect the required data and in identifying the methods to measure construction processes in detail. The questionnaire includes both open and closed questions to gain a broad perspective on actual and perceived benefits of 4D planning. To minimize the risk of collecting irrelevant data, a snowball sampling method was devised. A semi-structured interviewing technique was used to elicit information from various stakeholders to identify the key performance indicators at project level. The data and information obtained from semi-structured interviews was analysed using the Delphi technique. This technique was chosen since it is ideal for modelling real world phenomena that involve a range of viewpoints and for which there is little established quantitative evidence (Hanks and McNay 1999).

Three major construction projects in London (currently under construction with a combined value of £230 million) were selected for the research study and data collection. Initially, 42 industry decision-makers with experience in using 4D planning on construction projects were contacted and invited to take part in the research. Twenty-one respondents have accepted the invitation and have taken part in the interviews, resulting in a 50% response rate. Due consideration has been given in the selection of interviewee by selecting respondents (client, construction managers, general contractors, project managers and planners) with various roles and responsibilities on a construction project. In a sample size of 21 interviewees that took part in this study two (10%) were clients, three (14%) were general contractors, four (19%) were construction managers, five (24%) were planners, and seven (33%) were project managers on commercial projects in and around the city of London. They assisted in sharing the information on identification of 4D performance measures, how to collect the required data and in identifying the methods to measure construction processes in detail. The limitation of the study was its small interviewee sample size. The analysis of semi-structured interviews resulted in the development of following 4D-based KPIs as represented in Table 1.

Table 1: Definition of the identified performance measures

Measure	**Definition**
Time	It can be defined as percentage number of times projects is delivered on / ahead of schedule. The timely completion of a project measures performance according to schedule duration and is often incorporated to better understand the current construction performance
Safety	It can be defined as a measure of the effectiveness of safety policy and training of the personnel engaged in activities carried out on site. Safety is a major concern for every construction company, regardless of the type of work performed. Safety is normally measured quantitatively by Time lost as a result of accidents per 1000 man hrs worked and number of accidents per 1000 man hrs worked
Client satisfaction	Client satisfaction can be defined as how satisfied the client was with the product/facility. Usually measured weekly/monthly or shortly after completion and handover
Planning Efficiency	Planning efficiency has been represented in terms of Hit Rate percentage (%). Hit rate percent indicates the percentage (%) reliability of the commencement date for each activity or package(s) by comparing the planned programme against the actual programme
Communication Efficiency	Information exchange between members using the prescribed manner and terminology. The use of a 4D interface allows the project team to explore the schedule alternatives easily and assist in deploying 4D approach. Communication can be quantified in terms of number of meetings per week and time spent on meetings (Hrs) per week
Rework Efficiency	Rework efficiency can be defined as the activities that have to be done more than once in the project or activities which remove work previously done as a part of the project. By reducing the amount of rework in the pre-construction and construction stages, the profits associated with the specific task can be increased. Rework can be represented in terms of number of client changes, number of errors (drawing/design), number of corrections (drawing/design), number of requests for information to be generated, number of claims and number of process clashes spotted due to sequencing of activities
Cost	Percentage number of times projects is delivered on/under budget
Team Performance	Ability to direct and co-ordinate the activities of other team members in terms of their performance, tasks, motivation and the creation of a positive environment
Productivity Performance	This method measures the number of completed units put in place per individual man-hour of work. Some of the identified productivity performance measures are; number of piles driven/day, number of piles caps fixed / day, tonnes of concrete used / day/m^3 and pieces of steel used per day or week

First task for the interviewee were to identify and rank the performance measures using a four-point Likert Scale. The second task was to identify the data required to quantify each performance measure. Their input was considered to be critical in the success of this research. The potential reason behind conducting the semi-structured interviews were to evaluate how project and planning managers perceive the importance of performance measures; this will assist in the development of performance measures that can be used to quantify the value of 4D planning.

RANKING OF KPIS

Interviewees were asked to rank the identified KPIs. The ranking of the KPIs was done by using a four-point Likert Scale. For the prioritization process, each KPI was graded on a Likert scale of 1 to 4 (where 1= Not important, 2 = fairly important, 3 = Important and 4 = Very important) to measure the importance of each performance measure. The quantification of performance measure will be done on the basis of prioritized KPIs. The performance measures will be further classified in qualitative terms (rating on a scale) and quantitative terms (measurement units).Using responses from a four-point Likert Scale; the average weighted percentage for each performance measure was calculated. Figure 1 represents the weighted (%) ranking of the performance measures on the basis of the views of the respondents. The performance measures perceived as being highly important by the respondents are: *time, safety, client satisfaction, rework efficiency* and *communication efficiency.* As shown in Figure 1, time and safety has scored the top ranking as compared to other performance measures.

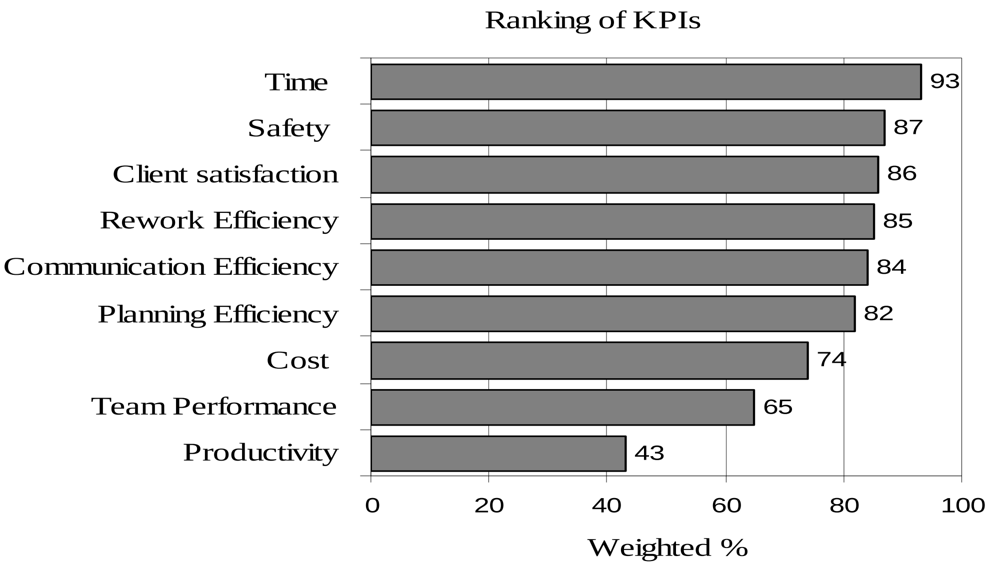


Figure 1: Ranking of KPIs

Table 2 represents the ways to quantify the prioritize 4D KPIs at the different stages of a construction project. For example, 'Time' has been ranked (93%) as top KPI by the respondents and we propose to use 'Schedule Performance Index' to measure it. Schedule performance index (Schedule efficiency) can be defined as the ratio of the earned value created to the amount of value planned to be created at a point in time on the project. Similarly, each of the KPIs will be quantified on the basis of set of performance measures as shown in Table 2.

Table 2: Ranking of 4D KPIs in order of priority

Ranking	KPIs	Performance measures	Stages of construction
1	Time	(i) Schedule Performance	Pre-construction & Construction
2	Safety	(i) Number of accidents per 1000 man hrs worked (ii) Time lost in accidents per 1000 man hrs worked	Construction
3	Client Satisfaction	(i) Number of client change order (ii) Number of client queries (iii) Satisfaction questionnaire (iv) Number of claims (time/cost)	Construction & Post-Construction
4	Planning Efficiency	(i) Percentage of activities started & completed on time (Hit Rate %)	Construction
5	Communication Efficiency	(i) Number of meetings per week (ii) Time spent on meetings per week (iii) Number of request for information responded	Pre-construction & Construction
6	Rework Efficiency	(i) Number of errors (Drawing) (ii) Number of corrections (Drawing/Design) (iii) Number of claims (Quality) (iv) Number of sequence clashes.	Pre-construction & Construction
7	Cost	(i) Cost Performance	Pre-construction & Construction
8	Team Performance	(i) Personnel turnover & productivity (ii) Timeliness of information from team	Pre-construction & Construction
9	Productivity	(i) Tonnes of concrete used per day / m^3 (ii) Pieces of steel used /day or week (iii) Number of piles driven / day (iv) Number of pile caps fixed / day	Construction

STATISTICAL ANALYSIS

The purpose of implementing statistical analysis techniques (correlation and multiple linear regression analysis) on this survey is to determine how time variable considered as a dependent variable influence by independent variables (safety, customer satisfaction, rework efficiency, communication efficiency, planning efficiency, cost, team performance and productivity). The method of data analysis adopted depends upon the complexity of the research problem. In this study, Spearman's correlation method and multiple linear regression analysis statistical tools were used for analysing the performance measures. Spearman's rank correlation is considered most suitable to test the association between any two variables and to show the probability of the association. Multiple regression is used to indicate the relative effects of independent variables on a dependent variable and the strength of relationships between the variables. SPSS software (Statistical Package for the Social Sciences) was used as the statistical tool for analysis.

Correlation analysis and multicollinearity

Correlation coefficient is a measure of the strength of any linear association between a pair of random variables. It measures how closely a change in one variable is tied to the change in another variable, and vice versa. Using SPSS tool, the correlation coefficient matrix obtained by the Pearson's correlation analysis is shown in Table 3. The first observation in Table 3 is that almost all the independent variables are correlated with the dependent variable (Time Y), i.e., there is a *dependence* of Y on X_1,

X_2,.... X_K. The correlation results indicate that Time variable is significantly and positively associated with rework efficiency (r=0.7, p<.01), communication efficiency (r=0.6, p<.01) and planning efficiency (r=0.6, p<.01). No significant relation was found between safety, customer satisfaction and productivity. This confirms that the independent variables which affect performance have been correctly identified. A better planning and communication of information can lead to decrease the amount of rework needed on a construction project. This will ultimately assist project management team to complete the project on time.

Table 3: Correlation matrix for performance measures

Performance measures	Time	Safety	CS	RE	CE	PE	Cost	TP	Productivity
Time	1.0								
Safety	0.2	1.0							
Customer Satisfaction (CE)	0.3	-0.1	1.0						
Rework Efficiency (RE)	0.7	0.5	0.2	1.0					
Communication Efficiency (CE)	0.6	-0.1	0.8	0.4	1.0				
Planning Efficiency (PE)	0.6	0.2	0.5	0.6	0.6	1.0			
Cost	0.5	0.7	0.0	0.6	0.1	0.4	1.0		
Team Performance (TP)	0.6	0.3	0.6	0.5	0.8	0.6	0.5	1.0	
Productivity	0.3	0.6	0.2	0.5	0.3	0.4	0.7	0.5	1.0

The correlation matrix is further used to check multicollinearity in the regression model. The severity of multicollinearity presence may usually be identified by inspection of the correlation matrix and the effect on the regression coefficients and their standard errors as a result of changing the mix of independent variables. The three variables i.e. client satisfaction, communication efficiency & team performance are highly correlated with each other. One possibility to solve multicollinearity is to drop from the regression analysis, variables which are a source of the multicollinearity *(Cooper and Weekes 1983).* If variable client satisfaction is dropped from the model, the adjusted R^2 reduces from 0.708 to 0.68 and similarly if variable communication efficiency and team performance is dropped from the model, the adjusted R^2 reduces from 0.708 to 0.67 & 0.70. Based on this reason, client satisfaction, communication efficiency and team performance is not excluded from the model, despite the presence of multicollinearity. The evaluation of the interview results indicates that the visualization of the model improves the understanding of the work package and scope of the work to both the client and team members. Consequently, they are able to communicate better with each other and increase the performance of the team.

Regression analysis

The details of the rating done by 21 respondents were in-put into the SPSS software and regression model was produced (Table 4). The predictive power of the model is judged through the statistical measurement coefficient of determination (R^2), which is a measure of the goodness of fit for the model. R^2 is used to measure the strength of the correlation when more than two variables are being analysed. The R^2 gives the proportion of the variance of Y, which is explained by the independent variables, reflecting the overall accuracy of the predictions. However, when the number of independent variables is introduced into the model, R^2 also increases. A better estimate of the model goodness of fit is indicated by *adjusted* R^2. Unlike R^2, it does not inevitably increase as the number of included explanatory/independent variables increases. Model uses eight independent variables (productivity, customer satisfaction, rework efficiency, planning efficiency, safety, team performance, cost and communication efficiency) and has an R^2 of 0.708. The regression results indicate that Time variable is positively associated with project performance variables (productivity, customer satisfaction, rework efficiency, planning efficiency, safety, team performance, cost and communication efficiency). As generally interpreted, this (R^2) value indicates that 71% of project performance can be explained by the independent variable. It is worth noting different research traditions have different interpretations of acceptable value for R^2. While engineering models seek a high degree of explanatory power for use in design, social science models are more necessarily limited. A time-series models tend to have a high R^2 of 0.5 to 0.7 (*Kennedy – 1998)*. The standard error is a measurement of the dispersion for the regression model's prediction power. The standard error of estimate is 0.52071, which is low.

Table 4: Summary table for regression analysis

R	R Square	Adjusted R Square	Std. Error of the Estimate
.841(a)	.708	.513	.52071

FINDINGS OF INTERVIEWS

Analysis of the information gathered through interviews has assisted in understanding how project and planning managers perceived the benefits of 4D planning, how it could be improved and what are the barriers in the implementation of 4D planning within the industry. A majority of the project managers felt that the use of 4D planning has assisted them in risk reduction in schedule programme, decreasing the amount of rework and reduction in overall project duration. Following are the benefits of using 4D planning on the basis of information collected from the interviews:

- Risk reduction in a programme.
- Detecting sequence clashes
- Improves visualization.
- Assist in reducing overall project duration
- Enhanced client satisfaction
- Assists in reducing the amount of rework required to be done.

Project managers felt that work force attitude (lack of awareness), lack of sufficient IT skilled people, resistance to change by general contractors were cited as the major concerns for successful implementation of 4D planning. The major impediments in the implementation of 4D planning in construction are:

- Lack of sufficient IT skilled people with the required knowledge of 4D.
- Time and money involved in training to upgrade the skills of work force.
- Resistance to change within the industry and to go through a new learning curve.
- Construction companies are not eager to invest in research and development.
- A lack of system compatibility, standardization and willingness of user to adopt this technology.

A due consideration should be given to the parameters like cost of the project, complexity of the project, risk involved and level of details required before developing the 4D models. There is a great need of improvement required to link the knowledge based system with the 4D models to analyse the feasibility of schedules from cost, safety, and other performance metrics viewpoint.

CONCLUSIONS

Findings of the interviews indicates that the industry is making less effort to reap the benefits of 4D planning and to improve the working practices at site level. Industry is still considering 4D as a demonstrative tool rather than a planning tool. To fully exploit the benefits of 4D technology, stakeholders are required to develop a new set of skills and implement organizational changes. There is a great need and demand to bring project team together at an early stage of the project. Designers are required to focus more on overall design and coordination of design tasks to avoid conflicts at construction stage. General Contractors are required to work more closely with designers from the design development stage to provide their valuable input at early stages of designing to capitalize the benefits of 4D planning. This will assists in addressing buildability and coordination issues during an early design stage of a construction project. As a consequences site efficiency can be improved by reducing the amount of errors, rework and waste involved during construction stage.

While there were some differences existed between owners and contractors relative to their views about 4D planning and its benefits, but there were common opinions among all stakeholders relative to the following points:

- All respondents felt that 4D planning is an effective project control tool for monitoring, planning and executing a project.
- Majority of the respondents felt that 4D planning is a beneficial in risk management applications.
- All respondents felt that 4D is an effective interpretative and communicative tool compared to 2D drawing approach.
- 4D facilitates in communicating the issues relating to construction of the interrelated works between the stakeholders and especially with suppliers.

This study has identified five key performance indicators consistently perceived as being highly significant at site process level are: time, safety, client satisfaction, rework efficiency and communication efficiency.

Future research activities

The future research activities will include:

- Continuing the interview process to further confirm the 4D-based KPIs.
- Collating and analysing the site data and to quantify the KPIs for three construction projects.
- Benchmarking the KPIs with industry norms and identifying the improvements in construction processes resulted due to the application of 4D planning.
- Conducting cost/benefit analysis.

REFERENCES

Bassioni, A H, Price, A D and Hassan, T M (2004) Performance Measurement in Construction. *Journal of Management in Engineering*, **20**, 42–50.

Chan, A P C and Chan, A P L (2004) Key Performance Indicators for Measuring Construction Success. *Benchmarking: An International Journal*, **11**, 203–21.

Chan, A P C, David, S and Edmond, W M L (2002) Framework of Success Criteria for Design/Build Projects *Journal of Management in Engineering*, **18**(3), 120–8.

Construction Best Practice Program- Key Performance Indicators (CBPP-KPI) (2004). Available online: http://www.dti.gov.uk/construction/kpi/index.htm

Cooper, R A and Weekes, A J (1983) *Data, models and statistical analysis*. Oxford: Philip Allan.

Cox, R F, Issa, R A and Ahrens, D (2003) Management's Perception of Key Performance Indicators for Construction. *Journal of Construction Engineering & Management*, **129**(2), 142–51.

Dawood, N, Eknarin, S, Zaki, M and Hobbs, B (2002) 4D Visualisation Development: Real Life Case Studies. *In: Proceedings of CIB w78 Conference,* Aarhus, Denmark, 53–60.

Egan, J. Sir (1998) *Rethinking Construction: The Report of the Construction Task Force to the Deputy Prime Minister*. London: Department of the Environment, Transport and the Regions.

Griffis, F H, Hogan, D and Li, W (1995) An Analysis of the Impacts of Using Three-Dimensional Computer Models in the Management of Construction. Construction Industry Institute. *Research Report*, 106–11.

Haymaker, J and Fischer, M (2001) Challenges and Benefits of 4D Modelling on the Walt Disney Concert Hall Project. *Working Paper 64*, CIFE. Stanford: Stanford University.

Hinks, J and McNay, P (1999) The creation of a management-by-variance tool for facilities management performance assessment. *Management Facilities*, **17**(1–2), 31–53.

Kam, C, Fischer, M, Hanninen, R, Karjalainen, A and Laitinen, J (2003) The Product Model and Fourth Dimension Project. *IT Con*, **8**, 137–65.

Kaplan, R S and Norton, P (1992) The Balanced Scorecard **--** Measures that Drive Performance. *Harvard Business Review*, **70**(1), 47–54.

Kennedy, P (1998) *A guide to econometrics*. 4Ed. Cambridge, MA: The MIT Press.

Koo, B and Fischer, M (1998) Feasibility Study of 4D CAD in Commercial Construction. *CIFE Technical Report 118.*

Latham, M. Sir (1994) *Constructing the Team:* Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry. London: HMSO.

Li, H, Irani, Z and Love, P (2000) The IT Performance Evaluation in the Construction Industry. *In: Proceedings of the 33rd Hawaii International Conference on System Science*

Messener, J I and Horman, M J (2003) Using Advanced Visualization Tools to Improve Construction Education. *In: CONVR Proceedings,* Virginia Tech. USA.

Songer, A (1998) Emerging Technologies in Construction: Integrated Information Processes for the 21st Century. *Technical Report,* Colorado Advanced Software Institute, Colorado State University, Fort Collins.

Songer, A, Diekmann, J and Karet, D (2001) Animation based construction schedule review. *Construction Innovation*, **1**, 181–90.

Staub-French, S and Fischer, M (2001) Industrial Case Study of Electronic Design, Cost and Schedule Integration. *CIFE Technical Report 122.*

SIMULATION AIDED PROJECT DECISION MAKING

Abdulsalam A. Al-Sudairi[1]

Associate Professor, Architectural Management Program, College of Architecture & Planning, King Faisal University, PO Box 2397, Dammam, 31451, Saudi Arabia

One important role of project managers is to make decisions before, during and after the project execution. Most of the time, these decisions are neither straightforward nor easy to take and therefore, they require careful analysis and evaluation, which might require a tool such as simulation. In order to assess the right decisions simulation perhaps is the most sophisticated tool for project managers. This paper demonstrates the potentiality of object-oriented simulation models in making hard decisions on a complicated construction project. The project is located in King Faisal University campus in Dammam, Saudi Arabia. By analysing its structural system and its architectural components, this building can be divided into smaller segments. Thus, there are different ways of sequencing the construction of this building. Making a decision on the optimum sequence is very crucial. Simulating the construction process of the aforementioned building required careful data collection through field observations and interviews. The purpose of this data was to describe the logic and the inputs to the construction process that are necessary for model verification and validation. With a verified and validated model one can evaluate the different ways of sequencing the construction activities of this case study. Object-oriented simulation models are absolutely essential in simulating construction processes because they fit the nature and the requirements of such processes. Building a sound simulation model starts with careful understanding of objects, their classes and how they are interrelated with each other.

Keywords: modelling, object-oriented, process, simulation.

INTRODUCTION

Management is about making decisions. In construction projects decisions are made on a daily basis where most of them are programmed. Programmed decisions are those that are made in accordance with some habit, rule or procedure. Stoner and Wankel (1986) pointed out that every organization has written or unwritten policies that simplify decision making in recurring situations by limiting or excluding alternatives. Unfortunately, not all decisions can be programmed because there are compound variables that may lead to different alternatives where each one has both advantages and disadvantages. Which alternative is the best remains a very difficult question to answer especially in large projects. To assess these solutions and to make the right decision, managers are advised to use sophisticated tools like object-oriented modelling. In fact, using traditional tools like CPM and PERT may lead to some disadvantages, such as time delays due to extended reviews (Bhuiyan and Thomson 1999; Wei *et al*. 2002). Besides, these tools are not dynamic and very difficult to perform what-if analysis.

[1] aalsudairi@kfu.edu.sa

This study demonstrates the use of object-oriented modelling in a relatively large construction project in order to determine the best sequence in constructing it. The construction project of the college of architecture and planning building in King Faisal University campus in Dammam, Saudi Arabia, was chosen as a case study and modelled in Extend+BPR®, which is an object-oriented simulation package. The simulation model focused on the construction process of the structure of the aforementioned project.

This case study concerns a three-storey building with almost 7000 m^2 per floor. Rethinking the work structuring of this project, one may come up with numerous ways of sequencing its progress. Such a case study could be constructed floor by floor or each floor may be divided into smaller segments so that construction progresses from one segment to another. Furthermore, segmentation of the project could be done according to its physical characteristics (e.g. structural/architectural) that may lead to a difficult situation of the work structuring of this project.

Different work structuring may affect the size of the work-in-progress (WIP). This is because work structuring breaks down a project into smaller production chunks that move in the value stream until they become the completed work (Tsao *et al*. 2000). The size of WIP, on the other hand, may increase or reduce cycle time of a production system. According to Little's law, the following formula for the relation of cycle time and work in progress in any production system can be derived (Koskela 1999):

$$\text{Cycle time} = \text{work-in-progress}/\text{throughput}$$

Thus, by reducing WIP, the cycle time is reduced, provided that throughput (throughput is the rate of, or interval between, finished products) remains constant.

Moreover, simulating construction processes requires careful examination of its flow units (which are known as *objects* in simulation terminologies), operations and their logic, inputs and outputs to these operations and so forth. Recognition of such issues is crucial in building a sound simulation model.

Thus, the main objective of this study is to investigate the potentiality of simulation in solving complicated problems that are almost impossible to solve with traditional methods. To construct a simulation model for the aforementioned case study, data collection and field surveys were conducted to identify model inputs and logic that are necessary for verification, validation and analysis.

THE NEED FOR SIMULATION IN CONSTRUCTION PROCESSES

Simulation is defined by Pritsker (1995) as the process of designing a mathematical model of a real world system and experimenting with the model on a computer. Simulation uses a computer program to actually mimic causal events and the consequent actions in a system (Harrel and Tumay 1997). Simulation is a management tool that does not typically generate an optimum solution to a problem (Moore *et al.* 1993). In fact, it is a solution evaluator; it directs one towards the best workable solution (Harrell and Tumay 1997).

The use of simulation for modelling construction activities enables the modeller to test almost all possible changes to a construction process and hence give a clearer picture of the optimum solution (Slaughter and Eraso 1997). In fact, Martinez and

Ioannou (1997) stated that simulation-based methods are almost universally accepted as the most effective because of their modelling versatility and power.

Utilizing simulation in construction processes needs thorough investigation. Each construction process is almost unique because of factors such as weather, site conditions and resources availability. The type of construction materials is also a critical model input. The delivery and unloading methods, the type and size of resources and the construction methods are all dependent on the type of material flowing in a process.

Halpin and Riggs (1992) developed four steps in model formulation. These steps are (1) flow unit identification (a flow unit could be a physical item of descriptive work); (2) development of flow unit cycles; (3) integration of flow unit cycles; and (4) flow unit initialization. One may notice that the flow unit is a key word in these four steps. This is because the selection of the flow unit dictates the degree of modelling detail incorporated into the simulation model (Halpin and Riggs 1992). For instance, identifying a material flow unit in a block-laying process could be laying a section of blocks or laying one block. In this case, the latter assumption would be more accurate than the former assumption because it almost mimics the real system. Fortunately, today’s simulation packages give the opportunity to go into such detail with relative ease.

The structure of the case study is mainly constructed from cast-in-place concrete. Because of that, a cubic metre of concrete is assumed to be the flow unit in the simulation model. To be more specific, each cubic metre was further identified according to its structural elements. The structural elements are footings, columns and slabs. The reason behind such detailing is that each element has certain requirements that may vary enormously. For example, the time to place a cubic metre of concrete for a footing is not like placing the same amount of concrete to a column.

With features offered in object-oriented simulation packages, going into such detail become very easy and more importantly suits the nature of construction processes. To be specific, modelling with object-oriented simulation packages is even more effective and easy when compared with other simulation packages (Al-Sudairi 2007; Cheng *et al*. 2006; Farrar *et al*. 2004). The remaining sections will discuss these issues in more detail.

What is object-oriented modelling?

Though it is not clear what makes certain software object-oriented many programmers, software professionals and end-user applications proclaim products that are object-oriented (McGregor and Sykes 1992). In addition, information technology experts do not agree about what actually constitutes an object-oriented simulation package. This study adopts the definition of McGregor and Sykes (1992), who claim that a software system supports three concepts namely *objects*, *classes* and *inheritance* to be considered object-oriented.

An object-oriented program is a software system whose components are *objects*. Each object is characterized by its own set of attributes and by a set of operations that it can perform (McGregor and Sykes 1992). Bank transactions, temperature degree in a room and processing a design/construction permit are all examples of objects. A cubic metre of concrete of a footing, a column or a slab is the basic object in the simulation model of the construction process. A combination of several cubic metres of concrete, which is the basic object, forms another specific object that could be the footing, column or slab.

A *class* is a set of objects that share a common conceptual basis. All objects in a given class have matching attributes and operations. For example, a column, which is one of the objects in the simulation model, has many classes according to its location and structural properties. As there are 144 columns per floor this has become very crucial in modelling the concrete structural process of this case study. Similarly, using an object-oriented simulation model made the identification of this large number of columns very easy. In general, object-oriented simulation packages support a graphical environment that makes the process of building a simulation model easier. In fact, the users do not have to access lower-level programming language details as well (Cheng *et al*. 2006; Laguna and Marklund 2005).

Inheritance is a technique for using existing definitions as the basis for new definitions (Law and Kelton 2000; McGregor and Sykes 1992). Here, *inheritance* means that if one defines a new object type (sometimes called a *child*) in terms of an existing object type (the *parent*), then the child type inherits all the characteristics of the parent (Law and Kelton 2000). Optionally, certain characteristics of the child can be changed or new ones can be added. As mentioned earlier, a cubic metre of concrete is the basic object and many cubic metres of concrete would generate almost new objects such as footings, columns or slabs. Figure 1 shows the inheritance concept of the simulation model of the case study where an *object* starts from a cubic metre of concrete to a part of the whole building. Here, the simulation run will be terminated once the building is completed.

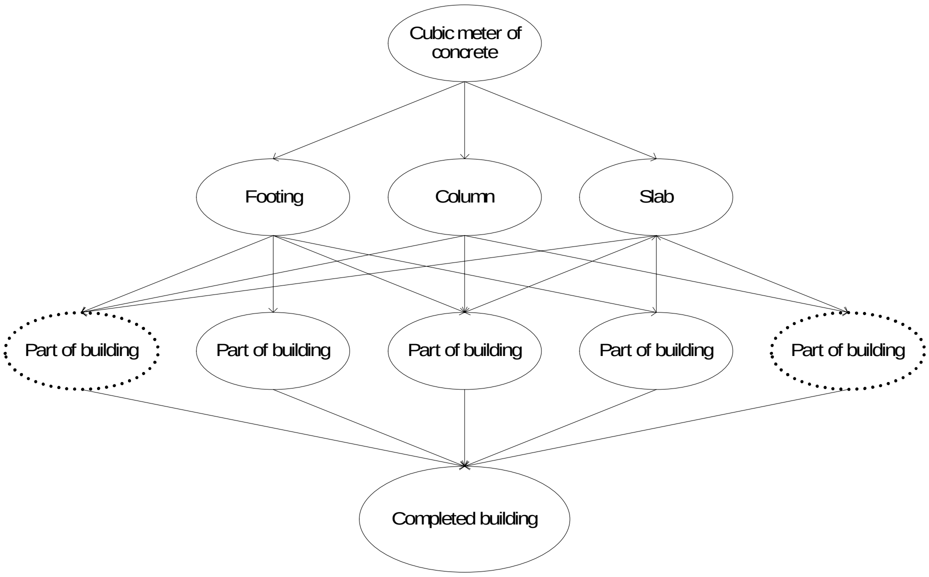


Figure 1: A hypothetical representation of the model objects

The logic of the model for this study was set to sequence construction activities of the footings, the columns and finally the slabs. It is true that there were similarities as well as differences among these specific objects. For instance, the time taken to strip the formwork of slabs was longer than those activities involved in both footings and columns.

In this study Extend+BPR® was selected because of its simplicity of use and its adaptability in modelling lengthy complex processes (Al-Sudairi 2007).

The most important parts of any Extend+BPR model are the *blocks*, the libraries where blocks are stored, the dialogues associated with each block, the connectors on each *block*, and the connections between blocks. A *block* specifies an action or process; it is used to represent a portion of a model. Some blocks may simply represent sources of information. Others may modify information as it passes through them. In other words, a block is a high-level modelling element for building simulations without programming (Extend 2002). Information comes into the block and is processed by the program that is embodied in the block. The block then transmits information to the next block in the simulation through connectors as shown in Figure 2.

Almost all blocks in Extend+BPR have input and output connectors, the small squares attached to the sides of a block. Input and output connectors are usually predefined and their function is known in advance. Connection lines are used to hook blocks together; they show the flow of information from one block to another through the model (Extend 2002). Figure 2 presents a small portion of the simulation model. In this study there were almost 100 blocks used for the construction process.

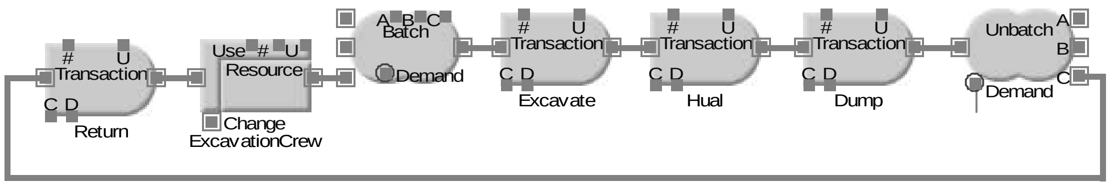


Figure 2: A small portion of Extend+BPR model that simulates excavation activities

CASE STUDY AND MODEL BUILDING

An empirical study is designed to demonstrate the potentiality of object-oriented modelling as a tool in managing construction processes. This study focuses only on the construction process of the skeleton; i.e. the model simulates excavation, backfilling, and all concreting activities of foundations, columns and slabs for all floors. Concreting activities included steel reinforcement, formwork, placing concrete and curing. Building a sound simulation model requires the following steps, which are basically the research methodology:

1. Data collection of the aforementioned activities (e.g. time and resources required to set formwork for a column) describes the logic of the model and its inputs. The sources of the collected data included drawings, bill of quantities performed by the general contractor, resources and their productivity rates, and a CPM schedule for the major phases in constructing the building. Certain cost data were gathered from the construction cost index manual prepared by Projacs (Projacs 2002).

   Figure 3 shows a typical floor plan of the case study. It is a rectangular floor plan with 110m in length and 64m in width. There is an atrium along the building dividing into two independent zones. Also, there are two expansion joints across the building dividing it into three independent areas in each floor (see Figure 3). With the atrium and the two expansion joints, each floor can be divided into six independent sections. Thus, there are four ways of structuring the work of this building which are (1) by levels (which is the actual/as-is case); (2) by zones; (3) by areas; or (4) by sections. Figure 4 conceptually illustrates these four scenarios.

The main structure of the building is a two-way concrete slab cast in place. The actual sequence of this building was done floor by floor and the construction took 360 working days to complete its skeleton.

The building is procured in a traditional design-bid-build with lump sum contract. The construction of the building began in September 1997 and was completed in October 2000.

2. Interviews with those involved in the design and construction of the case study are another source of information that serves two purposes. First, to get more data and confirm other data gathered in step one (e.g., the total time required to finish the whole skeleton, size and type of construction crew for certain activities, etc.). Secondly, to identify key experts for model verification and validation.

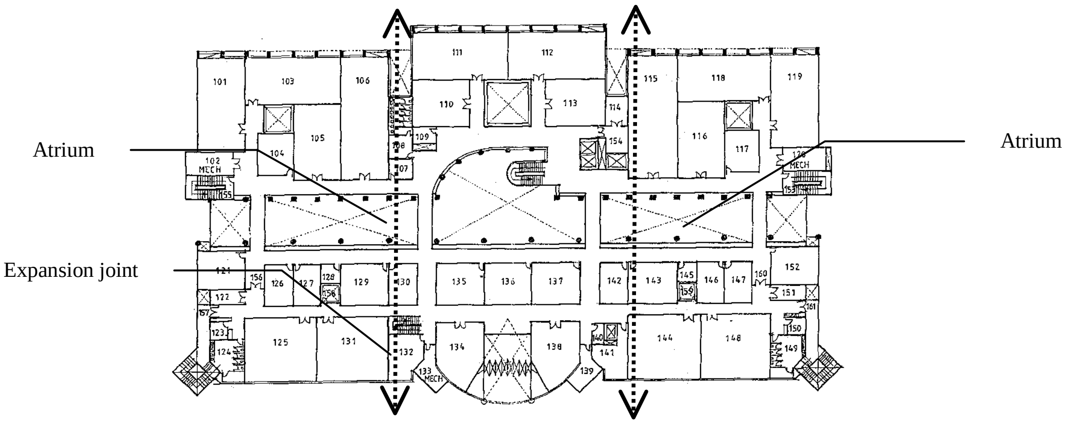


Figure 3: Showing the typical floor plan of the case study with its atrium and the two expansion joints

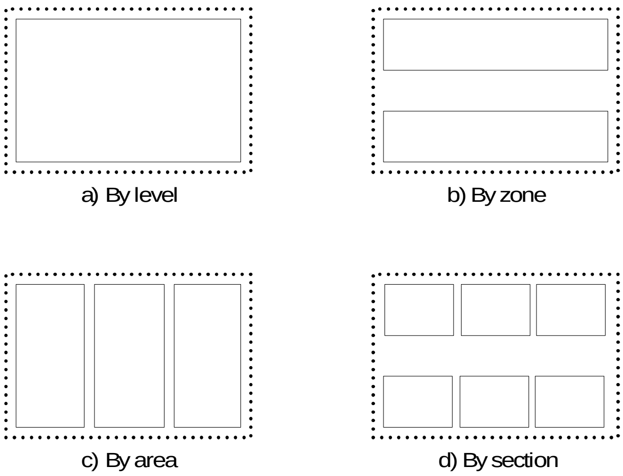


Figure 4: Showing the four possible scenarios in sequencing the construction process

3. Construct an initial model by simulating a small portion of the case study. In doing so, it is easier to verify the logic of the model. A complete model for the whole construction process of the skeleton was then constructed. The model simulates underground activities and overground activities. Underground activities include excavation, foundation and backfilling. Overground activities include column and slab activities for all floors.

Simulating the construction process of the aforementioned building required careful attributing of its objects (i.e. footing, columns and slabs). Each object in the model was identified by its structural function that varies from footings, columns or slabs and by its horizontal and vertical location. For instance, the model was designed to differentiate between two columns located on one level with different locations on the same level. This is accomplished by coding each column by its level, zone, area and section. In doing so, the model will not mix columns of section 1 with those in section 2 of the same level. Likewise, objects are identified vertically so that the model will not release objects of level 2 until all objects in level 1 are completed.

Table 1 shows a small portion of data input to the model that was utilized in order to differentiate between model objects and to be able to select any sequence of the four scenarios. The first column in Table 1 gives a code number to each column, which is a unique number so that the model can recognize each column individually. The remaining columns in Table 1 are set to identify each column according to its location. For example, column 72 is located in section 3 of area 2 of zone 1 on level 1, whereas column 73 is located in section 4 of area 2 of zone 2 on level 1. The same thing applies to footing and slab objects. It is worth mentioning that slabs in reality are not as clear as in columns or footings. For simulation purposes, the whole slab for each level in the case study was divided into smaller slabs according to columns carrying them. For example, a slab for a room with four columns will be divided into four slabs.

Table 1: A small portion of data input to the simulation model

Column	**Level**	**Zone**	**Area**	**Section**
71	1	1	2	3
72	1	1	2	3
73	1	2	2	4
74	1	2	2	4

4. Model verification is to ensure that every portion of the model operates as expected. Using features offered in Extend+BPR, such as animation, the author reached a confidence level that the model is functioning properly. Verifying a model does not mean the model is completed. One needs to make sure that the model is mimicking the real system.
5. Model validation means that the model is reflecting the actual system. The purpose of validation is to confirm the robustness of the simulation system by testing the simulation results for closeness to the actual system (Cheng *et al*. 2006). For instance, a project completion time of 330 days based on six working days per week and an eight-hour shift per day was obtained from the simulation model. This result was validated by comparing it to the actual completion time of major milestones as shown in Table 2.

Table 2: Comparing completion times of simulation results to actual data

Project milestones	**Simulation**	**Actual**
Substructure including excavation & backfilling	79 (day)	81 (day)
Ground floor	81	83
First floor	85	86
Second floor	85	85

Total		330	335

6. Model adjustment is carried out by looking into different scenarios with different work structuring that reflects the physical components of the case study as mentioned in step 1.
7. The results of the different scenarios of the valid model are compared with each other to reveal certain issues with respect to managing construction processes.

DISCUSSIONS OF MODEL COMPARISONS

For the sake of the research, the only change introduced to the 'as-is' model was the size of work that a construction crew can start with. The simulation model treated the size of WIP as the number of columns/slabs that vary according to the work structure, which could be by level (144 columns/slabs), by zone (72 columns/slabs), by area (48 columns/slabs) or by section (24 columns/slabs) as mentioned in step 1 of the previous section.

The second column in Table 3 shows the effect of reducing WIP to project cycle time, which is generally positive. There is a significant improvement in cycle time reduction, which is almost 17%, and better utilization; there is almost 30% improvement in crew utilization. When work structuring goes by 'area', there are enough workable activities on different segments of the building. That is, one crew could be working on foundations in one area while another crew is working on columns in another area. This means that work structuring led to a better synchronization and alignment of the construction activities where construction crews are kept productive most of the time.

Table 3: Comparing results of all scenarios

	Cycle time	**Total cost**	**Productivity**	**Utilization**
Level (as-is)	330 (days)	$296075	0.76 (M^2/hour)	61 %
Zone	277	$252852	0.97	71
Area	275	$250709	0.99	72
Section	318	$290850	0.82	62

However, the effect of reducing WIP to cycle time is not always exact, i.e. less WIP does not necessarily mean less cycle time. The least WIP (i.e. at 24 columns/slabs) reduced cycle time marginally as opposed to moderate WIP (i.e. at 48 columns/slabs) that reduced cycle time significantly (see Table 3).

Comparing the previous results to Little's formula, one notices a contradiction. This is because one condition of Little's formula is to have minimal waiting time between sub-processes. In construction projects, especially in cast-in-place concrete processes waiting time is inevitable. The waiting time in this case study ranged from two to three weeks that led to multiple stops and hence poor production. In fact, Santos *et al*. emphasized the role of technological innovation to reduce decoupling between processes so that they can start earlier (Santos *et al.* 2000). That is, one way of reducing waiting time in concreting processes is by adding certain admixtures to concrete so that it can set faster leading, to less waiting time.

Another lesson learned from simulation is that there could be more than one good solution with different ramifications as shown in Table 3, which is also consistent with the results of Al-Sudairi *et al*. (2000). The cost measure in Table 3 was only obtained from the direct labour expenses in constructing the building. The utilization measure is the percentage of time that a construction crew is actually engaged in primary work. Table 3 summarizes simulation results where the only change was the WIP. Other issues such as manpower and material availability, weather and learning curves are not considered in this model. Considering these issues would definitely lead to multiple scenarios with different results. For instance, taking into account concrete formwork would add another difficulty to the decision-making process. That is, the least WIP would require less formwork with multiple usages that may require getting extra formwork. However, the largest WIP would require larger formwork with few usages that might not require any extras. Having said that, it is difficult to analyse a problem of this nature with traditional tools; indeed, simulation is one of the right tools that gives the opportunity to explore and evaluate multi-dimensional problems.

Again, object-oriented modelling gives us the opportunity to examine the impact of waiting time between concreting activities to the total cycle time of the construction process. To test the impact of waiting time to WIP, a hypothesized waiting time was introduced to the model. Results presented in Table 4 are based on a hypothetical waiting time between sub-processes, which ranged from one day to seven days, just to show the importance of overcoming decoupling between processes and making them flow continuously. When waiting time is one day Little's formula became absolutely true. The least WIP led to the highest reduction in cycle time.

Table 4: The impact of waiting time to the total process cycle time (days)

Waiting time	Level	Zone	Area	Section
One day	248	216	210	204
Two days	260	218	212	206
Seven days	272	223	217	216

It is apparent from the findings presented in this paper that simulation is indeed a powerful and flexible tool. It is powerful because it enables the modeller not only to consider many factors but also to measure the impact of each factor to the simulated system. Likewise, simulation is flexible tool because it can accommodate multiple scenarios in one model. The simulation model of this study was set so that it can mimic the four scenarios with little changes. Moreover, questions like: what things management should give up in the current practice; what are the consequences of adopting certain changes; what is the most effective scenario, and so forth can be answered easily. These features are very difficult to obtain when using other tools.

The three concepts (*object*, *class* and *inheritance*) associated with object-oriented modelling are absolutely essential in simulating construction processes because they fit the nature and the requirements of such processes. Building a sound simulation model starts with careful understanding of objects, their classes and how they interrelate with each other. In construction projects, objects vary from one process to another, which poses another difficulty in modelling them. Simulating a block-laying process is not like simulating a steel erection process. Therefore, the objects in the later process, which are steel members, are not as interchangeable as the objects, which are blocks, in the former one. Appreciation of this fact is the first step towards sound simulation models because it enables the modeller to be as close as possible to the real construction process.

One may argue that modelling with simulation takes time and effort and is also very difficult to verify and validate. This is truly a misconception as modern simulation packages are object-oriented and usually associated with graphical environments that do not need a sophisticated programming background. Equally it is very easy to construct, and also flexible for changes if necessary.

CONCLUSIONS

This study advocates the use of object-oriented simulation modelling as an essential tool for analysing and evaluating construction processes. The construction process for architecture and planning for building presented in this study is very difficult to analyse and to reach an optimum solution with traditional tools. Indeed, simulation is a superior tool due to its numerous advantages as being dynamic, flexible and beneficial through all project phases.

Identifying objects and systems that usually govern them is crucial in simulating construction processes using object-oriented modelling tools. The complicated case study presented in this paper was easily evaluated by using this tool.

One great lesson that can be learned from simulation is that there could be more than one good solution with different ramifications. The best solution may be hindered by traditional practices such as bad process design. In addition, factors like material and labour availability were not considered in the simulation model that would definitely add another dimension to this study.

The improvement gained by reducing the size of work-in-progress is mainly limited by waiting time and decoupling between processes. Reduction of WIP requires smooth flow in the value stream that in turn leads to cycle time reduction and better crew utilization. This means great savings in effort, time and cost that are fundamental in managing construction projects.

REFERENCES

Al-Sudairi, A (2007) Evaluating the effect of construction process characteristics to the applicability of lean principles. *Journal of Construction Innovation*, **7**(1), 99–121.

Al-Sudairi, A, Diekmann, J and Songer, A (2000) Interplay of project complexity and lean methods. *In*: J Barlow (Ed.) *8th Annual Conference of the International Group for Lean Construction*, 17–19 July 2000, Brighton, UK.

Bhuiyan, N and Thomson, V (1999) The use of continuous approval methods in defence acquisition. *International Journal of Project Management*, **17**(2), 121–9.

Cheng, M, Tsai, M and Xiao, Z (2006) Construction management process reengineering: organizational human resource planning for multiple projects. *Journal of Automation in Construction*, **15**(6), 785–99.

Extend (2002) *Extend v6: professional simulation tools*. Imagine That Inc., User's Manual for Extend, available at www.imaginethatinc.com.

Farrar, J, AbouRizk, S and Mao, X (2004) Generic implementation of lean concepts in simulation models. *Lean Construction Journal*, **1**, 1–23.

Halpin, D and Riggs, L (1992) *Planning and analysis of construction operations*. New York: John Wiley & Sons.

Harrell, C and Tumay, K (1997) Simulation made easy. *IIE Solutions*, July, 39–41.

Koskela, L (1999) Management of production in construction: a theoretical view. *In*: I Tommelein (Ed.) *7th Annual Conference International Group for Lean Construction*, 26–27 July 1999, University of California, Berkeley, California, USA, 241–52.

Laguna, M and Marklund, J (2005) *Business process modeling, simulation and design*. New Jersey, USA: Pearson Prentice Hall.

Law, A and Kelton, D (2000) *Simulation modeling and analysis*. 3ed. Boston, MA: McGraw-Hill.

Martinez, J C and Ioannou, P G (1997) State-based probabilistic scheduling using STROBOSCOPE's CPM add-on. *In*: S Anderson (Ed.) *Construction Congress V*, 5–7 October, Minneapolis, USA.

McGregor, J and Sykes, D (1992) *Object-oriented software development: engineering software reuse*. Boston, MA: International Thomson Computers Press.

Moore, L J, Lee, S M and Taylor, B W (1993) *Management science*. 4ed. Boston, MA: Allyn and Bacon.

Pritsker, A (1995) *Introduction to simulation and SLAM II*. New York: John Wiley & Sons.

Projacs (2002) *Construction cost index-labor items*. Riyadh Chamber of Commerce and Industry-General Directorate of Contractors.

Santos, A, Powell, J and Sarshar, M (2000) Reduction of work-in-progress in the construction environment. *In*: J Barlow (Ed.) *8th Annual Conference of the International Group for Lean Construction*, 17–19 July 2000, Brighton, UK.

Slaughter, S and Eraso, M (1997) Simulation of structural steel erection to assess innovations. *IEEE Transactions on Engineering Management*, **44**(2), 196–207.

Stoner, J and Wankel, C (1986) *Management*. Englewood Cliffs, NJ: Prentice Hall.

Tsao, C, Tommelein, I, Swanlund, E and Howell, G (2000) Case study for work structuring: installation of metal door frames. *In*: J Barlow (Ed.) *8th Annual Conference of the International Group for Lean Construction*, 17–19 July 2000, Brighton, UK.

Wei, C, Liu, P and Tsai, Y (2002) Resource-constrained project management using enhanced theory of constraint. *International Journal of Project Management*, **20**, 561–67.

IMPROVING CONSTRUCTION AS AN ECONOMIC SECTOR: SOME REFLECTIONS

Francis T. Edum-Fotwe[1] and Ronald McCaffer

Department of Civil and Building Engineering, Loughborough University, LE11 3TU, UK

The drive for continuous and significant improvements and productivity gains in the construction sector has received attention from different stakeholders associated with the sector. Much of the initiative to improve construction was prompted by similar gains that attended the manufacturing sector after the latter sector had undergone a transition from a craft-based to a process orientation, with many of the processes being automated. The significant improvement in the manufacturing sector prompted the adoption of a programme in the 1990s to reform the construction sector in the UK to reflect a more manufacturing outlook for its operations and business activities. While this initiative produced several notable developments, there have been queries raised in recent times on how the sector's performance can be improved on a sustainable basis. For any sustainable improvement scheme to work effectively, it has to be accompanied by a shift in the cultural perspectives for improvement in construction. Within the paper the authors explore the general concepts of improvement and innovation as well as the nature of innovation in the construction sector. They address the apparent slow rate of innovation that has been associated with construction for several decades. They also make the case that much of the transformation which the sector would have to undergo to enable construction to attain the same levels of improvement and innovation as obtains in the manufacturing sector would have to be a cultural reorientation to make innovation the norm, rather than the exception. A framework to support the formal execution of continuous innovation is presented.

Keywords: construction, culture, improvement, innovation, systems.

INTRODUCTION

The 1990s saw unprecedented efforts by the UK to transform its construction sector from its traditional approach to delivering projects to become more of a manufacturing process (M4i 2000). This was conducted under the flagship Innovative Manufacturing Initiative, aimed at stimulating innovation across different industrial sectors within the UK (Graves *et al*. 1998). Construction's programme under the Innovative Manufacturing Initiative scheme was captioned under a theme of construction as a manufacturing process. The rationale of 'Construction as a Manufacturing Process' was to encourage construction to adopt and emulate the process orientation widely reflected by the manufacturing sector. The aspiration of Construction as a Manufacturing Process was to stimulate similar levels of productivity gains and operational improvements that attended the transition from functional to process orientation by the manufacturing sector (McCaffer and Edum-Fotwe 2003; Winch 2003).

[1] f.t.edum-fotwe@lboro.ac.uk

Within this paper, the authors explore the general concept of innovation and the nature of innovation in the construction and other sectors. The authors give attention to the apparent slow rate of innovation that has been associated with construction for several decades. They argue within this paper that a root and branch examination of the various systems that make up construction would have to be performed to enable construction to attain the same levels of innovation as obtains in the manufacturing sector. Fundamental to the transformation that the sector would have to undergo is a cultural reorientation to make innovation the norm, rather than the exception at all levels within construction. A framework to support the formal execution of continuous innovation is presented.

DRIVE FOR IMPROVEMENT IN CONSTRUCTION

Concern for improvement of the construction sector has been shared over the years, with several reports commissioned to address various issues that were considered as relevant to construction performance (Langford and Murray 2003). The Technology Foresight Panel (1995) for example, provided a catalyst for construction to see its processes from this business perspective. Subsequent developments, such as Egan (1998) and its forerunner, Latham (1994), adopted the view of a *customer or client is king* focus, with recommendations for improvement in the value that clients gain from implementing projects. The closer focus on the requirements of the client advocated by Egan (1998) was also a response to domestic competition and emerging economic realities from increasing globalization. The arrival of various benchmarking schemes including the European Construction Institute Performance and Process Benchmarking Initiative provided channels for attaining the business and organizational improvement implicit in such a client orientation. The related key performance indicators from the Construction Best Practice Programme, and the Movement for Innovation (M4i 2000) were aimed at spearheading a nationwide improvement in the sector. The impact of these initiatives, along with developments that have continued from the new initiatives, has been a new way of doing business in construction (Egan 2002). For example, new forms of contract, such as two-stage design and construct, contract management, private finance initiatives (and public–private partnerships) are fostering a new business climate for the sector (HM Treasury 2000).

These changes are contributing to a re-definition of the roles and positions of key stakeholders within the sector. For example, there has been a gradual shift observed in the role of the architect, which had hitherto been a *lead* for the project team in the building sub-sector of construction to *concept guardian*, with the managerial leadership subsumed by other professionals (Edum-Fotwe and Thorpe 2002). Equally observable is the growth of supply chain principles in the sector, spurred on by a need to bring about better alignment of the various supplier organizations that provide inputs to the project. The initial efforts on supply chain improvement addressed the physical logistics. Later developments saw the inclusion of information resources in improving logistics. To be able to put some these improvements achieved through the efforts of Construction as a Manufacturing Process agenda, it is important to place such achievements in the light of what constitutes innovation and how it may be stimulated in construction.

INNOVATION AS KEY TO IMPROVEMENT

The concept of innovation addresses both incremental and radical changes to processes, services and products of a company or an industrial sector. According to Christensen *et al*. (2004), the primary goal of innovation is often to solve a problem by bringing to life ideas generated through creative talent. The nature of the problem could range from the very technical such as addressing operational inefficiency or correction of design error, to the more subtle business requirement, such as the need for market growth. As such, the motivation for, and scope of innovation undertaken by, an organization could vary extensively in scope and often would involve considerations that transcend one single discipline (European Commission 2006). Figure 1 illustrates different categories of improvement that a construction organization may have to confront and identifies these as seven primary types of innovation. The next sections address each category of innovation briefly.

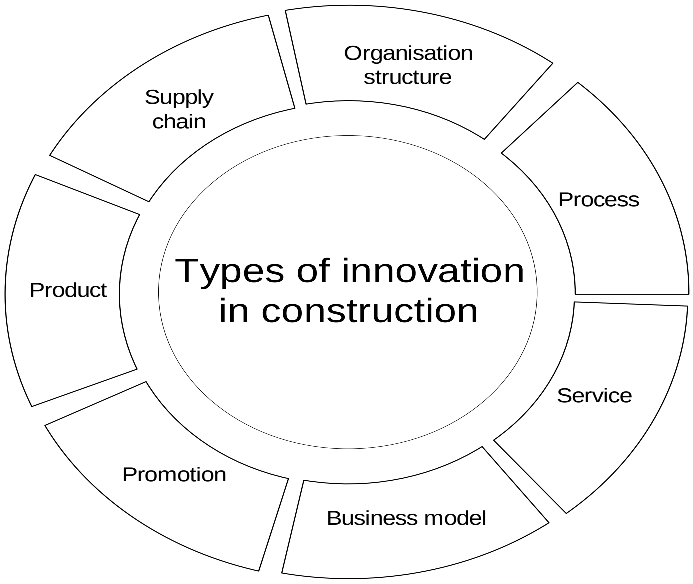


Figure 1: Innovation categories for construction organizations

NATURE OF CONSTRUCTION INNOVATION

There are two modes by which a construction company can implement innovation. These are incremental mode and radical innovation mode. The two modes are not mutually exclusive and one mode can be used to support the other in a programme for company or industry improvement. The incremental mode involves improvements whereby small changes are made to existing processes, products and practices, without altering the essential nature of the company's activities. The radical mode on the other hand entails a substantial overhaul of the organization's systems. It questions the raison d'être of each part of the organization, and often will result in a significant change in the purpose and basis for conducting the activities of a company (Tucker 2002; Turner 2006).

Figure 2 illustrates progress in performance improvement for two organizations, A and B. Organization A's incremental innovation efforts over time would result in a performance gap of $P_{b1} - P_{a1}$, which will widen over time.

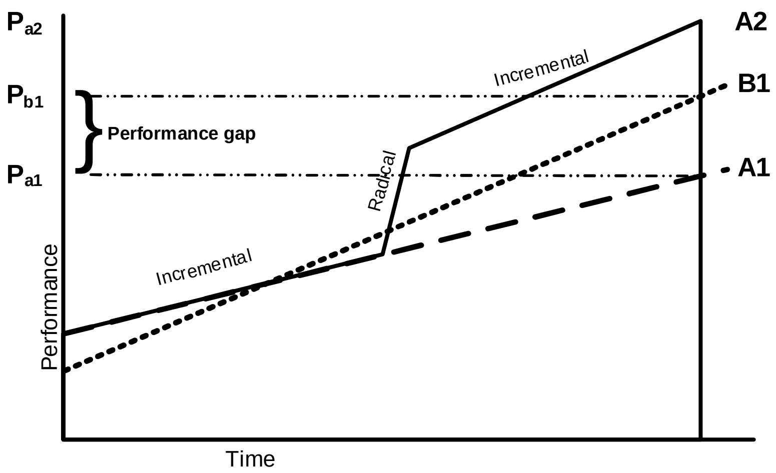


Figure 2: Nature of innovation in construction

The only means for addressing the performance gap is for Organization A to undergo a transition through radical innovation for a majority of the innovation categories outlined in the earlier sections of this paper.

The timing of radical innovation by a construction company is crucial as it enables an organization to inject a new pace into its activities and prevent the onset of obsolescence (Senge *et al*. 1999). Incremental innovation on the other hand is required all the time. Identifying what aspects organizations should earmark for incremental innovation and the frequency of conducting radical improvement is a capability that is essential for maintaining competitive advantage (Oke 2001).

While construction can boast of exemplar cases of leading edge developments, such exemplar developments are not widely shared across the whole of the industries making up the construction sector. This is due to the time constraint faced by most companies as well as the heightened levels of competition that characterize construction (Gregory and Deasley 2002). Typically therefore, a greater proportion of the effort of most construction executives is devoted to achieving and addressing the efficiency of the tasks they undertake rather than exploring radical alternatives for more effective solutions. Any improvements and innovations are therefore conceived within the limits that enable construction executives to maintain the same degree of control of the procedures involved in the tasks they undertake. Construction's posture on innovation as a result tends to reflect an incremental mode, whereby executives contemplate only small changes that do not dramatically alter their current operations and business. While the pursuit of such an incremental mode for innovation may be good in its own right, any organization that adopts only that posture potentially runs the risk of being overtaken by the competition.

SECTOR-WIDE DIMENSION OF INNOVATION

While it is easy to identify isolated cases of innovation by individual organizations at company or project level, the extent to which these isolated innovations are shared across the sector is more difficult to classify. Figure 3 presents a profile of innovation effort within construction at the organizational level and how the individual efforts are reflected through the whole sector. The essential argument that is presented in Figure 3 is that construction's innovation and improvement efforts tend to reflect the technical/technology and/or society and community driven factors. Notable in the technology stream of factors is the use of ICT, and similarly for society and the community is the reputation of the company and the sector as a whole. While the economic aspects of the sector receive much attention, there is relatively little or no effort in innovation or radical improvement in productivity that attends the economic considerations (Latham 1994; Egan 1998 and 2002). This is in part due to the context of economics within construction. Traditionally, economics in construction has focused predominantly on the optimization of onsite tasks and functional activities (Edum-Fotwe 2000). A fuller discussion of the sub-categories of technical, economic and society factors has been provided as part of the SUE-MoT project funded by the Research Council in the UK.

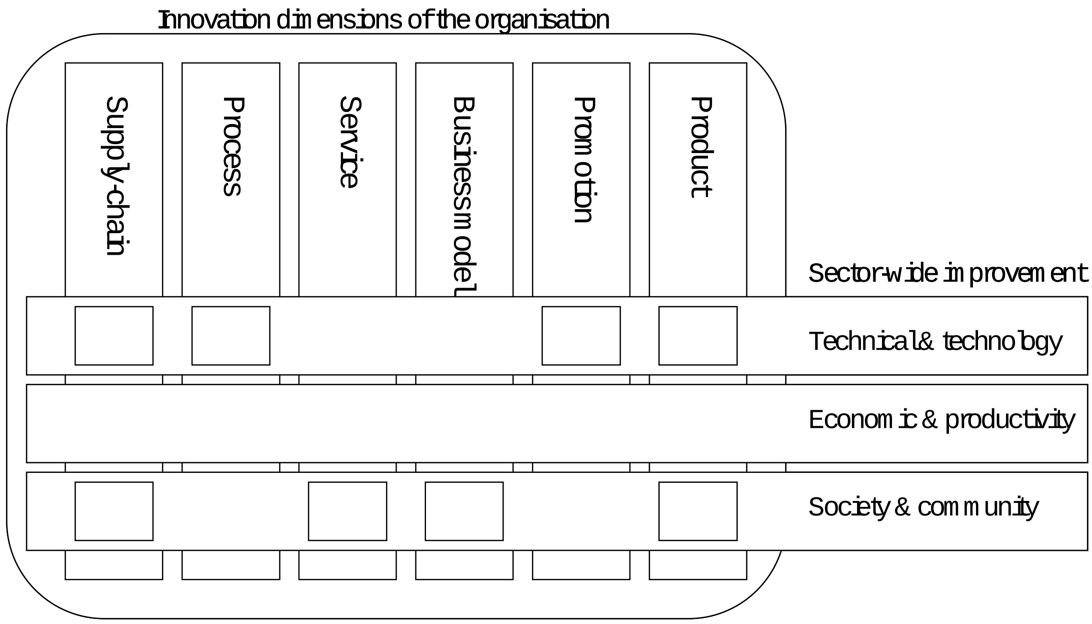


Figure 3: Innovation efforts across different dimensions in construction

The absence of or limited effort in economic innovation has contributed to a situation whereby the economic motivations of the construction sector appear to lag behind that of other sectors. The nature of economic realities that led to the development of the concepts of business and economic activities for the construction industry have undergone significant changes (Flanagan *et al*. 1998). It therefore calls for a revisit to the fundamentals of what constitutes the construction economy – its scope and areas of activity, as well as how it can be made to address present realities and potential changes likely to impact on the sector. This can be achieved by giving attention to the theoretical foundations that give rise to the activities of the industry along the current applied orientation for its research and professional practice.

Construction economics – its scope and development

Construction economics broadly addresses the use of economic concepts for the operations and activities of the construction industry. It involves the application of the principles and know-how of economics to the business and production processes of the construction industry. This includes economic options of design solutions comprising design economy and cost planning, economic considerations for translating design solutions into physical facilities to meet defined requirements, and methodologies for cost estimating and control. It also involves the economic functioning of firms within the construction sector as well as the relationship of the sector to national and international economies.

The need for a wider scope

The outlined areas of focus for construction economics within the industry's activities clearly reflect the Adam Smith concept of 'how scarce resources are allocated among the alternative users' as in general economics. It can be argued therefore that construction economics is no different from general economics or, for that matter, economics for any other sector of production. Ofori (1994) however, has suggested that construction economics developed as an outcome of the unique nature of the construction industry, which is characterized by large and expensive physical products, a complex industry structure and production processes, and a distinctive method of price determination. This underlying character of construction means that some of the generic principles from mainstream economics need to be fine-tuned to ensure their applicability to the industry's context. Equally, it calls for an appreciation of the underlying theories that drive the economic activities of the industry and its associated processes aside from the general principles of economics. In practice however, the development of construction economics has largely been influenced by its relationship to the industry and professional institutions associated with quantity surveying, commercial management, engineering economics, development economics, and investment and finance. The rationale for this strong influence is that construction economics is an applied subject and as a consequence its research focuses on the applied to the exclusion of the broader understanding of the theories that characterize construction activities. Commenting on this Betts and Wood-Harper (1994) suggested that the subject area appears to be developing in an evolutionary way based on the culture of industry practices, and largely unaffected by mainstream economic concepts and theories. This lack of strong foundation within mainstream economics and management for construction economics might be accounted for by the fact that construction has always seen itself as part of engineering. As such its principles of economy are predominantly based on and influenced by engineering concepts. Therefore, in order that such theories from mainstream economics can have a place in construction economics, research effort needs to be devoted to the demonstration of the applicability of these theories to the construction context.

According to Bon (1989) construction economics has focused on forecasting the economic consequences of a building decision on the basis of ever more extensive historical data about individual buildings and their components. However, the key task of building economics is to assist the decision makers concerned with building economy in their day-to-day operations involving the entire real property holdings at their disposal. Bon (1989) goes on to argue that the problem with the old focus of the field is twofold. On the one hand, the economic history of building activity is an important area of study in its own right, but the practical significance of building economics hinges on the field's sensitivity to the anticipation of continual economic change facing decision makers. This necessitates a viewpoint much broader than a prediction of the potential impact of the decisions relating to a single project. In addition Bon (1989) describes the record for the use of economic forecasting within the construction sector as not convincing over the extended periods of time associated with the building life cycle. To address this apparent shortcoming of construction economics, Bon (1989) advocates that the focus of the subject should be shifted away from investment decisions to decisions concerning the use of capital. His more significant argument was the view that such an active orientation on capital decisions for the problems of construction economy would require investigations of the theoretical underpinnings for economic activities within construction.

Modern economies are no longer based on the simplistic concept of mass production and consumption of goods and services (Green 1998). There is ample evidence to suggest that in very many instances, producing more in the current changing environment, however efficiently, is not necessarily better in terms of the strategic goals for every business. While lessons on this can be readily drawn from the IT sector, some vivid analysis can be established with the housing sector. This is perhaps epitomized by the trend towards downsizing and repositioning to focus on core business for several major construction organizations to increase productivity in the short term. However, downsized organizations often have to face a future that suffers from low financial performance if their first and repeat business is dependent on labour-intensive operations, which is the case for construction (Edum-Fotwe 1995). Its operations and processes are dominated by a high labour content. The picture here is that the sector is changing, and therefore the economics concepts and theories need not only to respond to such changes, but also to understand the dynamics of the new and evolving form of economy. This paper argues that it is not just economies that are changing. Economic theory is itself responding to the challenge of rapidly moving events. Construction economics therefore ought to take a look at new approaches as well as the established orthodoxy, and systematically build up an understanding of economic theorizing so as to offer opportunities and ideas to practitioners for application to real problems.

IMPROVING THE CONSTRUCTION ECONOMIC SECTOR

Clearly, there is a role for research in engendering the new agenda of a broader scope for the subject and responding to changing economics as advocated in the previous sections. Within the CIB, the work of the various task groups and working commissions already reflects some of the aspects of a broadened scope for the subject (Bröchner 2003). These need to be integrated to give construction economics a more defined role so that areas of economics not so represented can be addressed. Research in construction economics should be able to reflect adequately the sum total of economic activity within the construction sector. Also such a broadened scope could give attention to the new and emerging economics required for the sector, and its relationship to national and international economies.

THE WAY FORWARD

To overcome some of the weaknesses discussed in the foregoing sections of this paper it is expedient to have a generic framework for implementing innovation that can be employed at both organization and sector level. Such a solution will help to make construction's efforts to become innovative on a sustainable basis a formal activity that could lend itself to better planning and management. Figure 4 presents a flow process for the generic framework for implementing and managing innovation. The framework results in an innovation system that is implemented at either organization or sector level. The additional system inputs reflect unmanaged and managed environments. The unmanaged environment is represented as leadership, ideas bank, individual initiative, imposed innovation and unintended innovation.

The managed environment consists of structural changes, resources and enabling technologies, sub-processes and procedures, and a supportive culture that nurtures innovation. The persistent use of the framework should help to engender a culture of incremental and radical innovation in balanced proportions and make innovation the norm for construction (Drayton 2006).

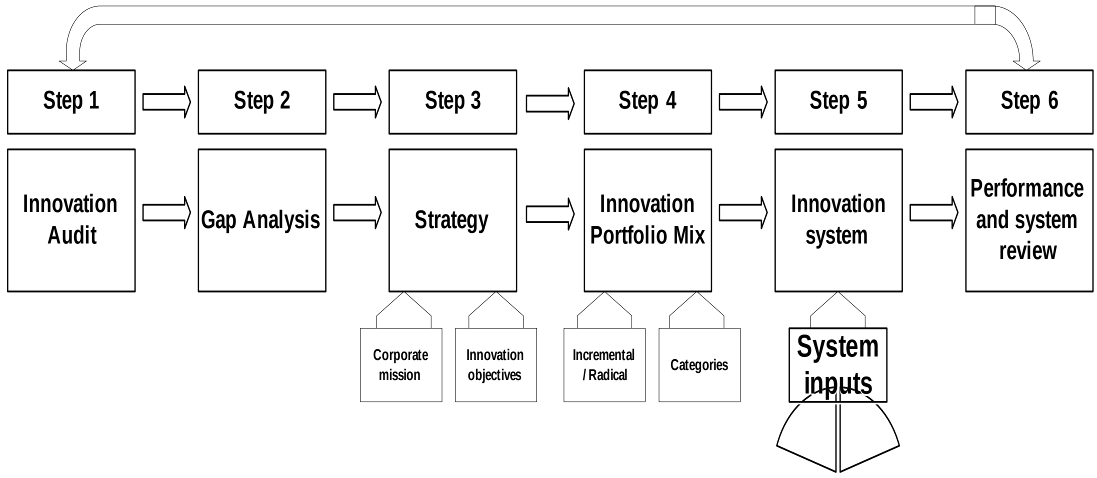


Figure 4: Framework for implementing innovation in construction

Additional to the implementation of the framework, there are other issues such as professional development programmes, education and training and possible regulatory instruments to foster innovation that will need to be in place. Some of the changes implicit in addressing each of these issues will be influenced by budgetary allocation. However, much of the change that will have to be advanced to make innovation a norm in construction will have to be cultural. An example will be a shift in professional boundaries to eliminate the *silo mentality* that prevails within the sector, to enable innovations that straddle different professions to be contemplated. Of equal relevance will be the alternatives put forward by Bröchner *et al*. (2005) and Winch (2006).

CONCLUSION

Within this paper the authors have explored the nature of innovation and the extent to which it pervades across construction as a sector. In an era when clients no longer demand the same price as the last project, but want reduced prices consistent with maturation of each process and product, it is important for construction to accelerate its innovation capability. The review of innovation efforts in construction indicates that construction operates at a sub-optimal level. The sub-optimality is accounted for in part by the focus of innovation within the sector. The focus of innovation within construction reflects technical and society factors, and less so economic ones. As such the causes of the sub-optimal levels of innovation can be traced to the nature and structures of the sector, as well as the arrangements for delivering its projects. In addition, the cultural posture within construction at both sector and company level inadvertently militates against the adoption of innovation. As a consequence, innovation effort in construction is predominantly informal, and often happens through serendipity. A framework to overcome the present informality as well as providing a systematic method for implementing innovation has been presented. The use of the framework at organization and sector level should enable construction companies to become more innovative.

REFERENCES

Betts, M and Wood-Harper, T (1994) Re-engineering construction: a new management research agenda. *Construction Management and Economics*, **12**(6), 551–6.

Bon, R (1989) *Building as an economic process: an introduction to building economics*. Englewood Cliffs, NJ: Prentice Hall.

Bresnen, M and Marshall, N (2001) Understanding the diffusion and application of new management ideas in construction. *Engineering Construction & Architectural Management*, **8**(5–6), 335–45.

Bröchner, J (2003) Integrated development of facilities design and services. *Journal of Performance of Constructed Facilities*, **17**(1), 19–23.

Bröchner, J, Josephson, P-E and Alte, J (2005) Identifying management research priorities. *Construction Management and Economics*, **23**(8), 793–6.

Christensen, C M, Roth, E A and Anthony, S D (2004) *Seeing what's next: using theories of innovation to predict industry change*. Boston: Harvard Business School Press.

Drayton, W (2006) Everyone a changemaker: social entrepreneurship's ultimate goal. *Innovations: Technology, Governance, Globalization*, **1**(1), 80–96.

Drucker, P (1994) The theory of business. *Harvard Business Review*, Sept/Oct, 95–104.

Edum-Fotwe, F T (1995) Enhancing quality in construction management education through research: a look at the importance of methodology. *Education for Construction Management*, The Australian Institute of Building Papers, Special Volume, No. 1, 48–56.

Edum-Fotwe, F T and Thorpe, A (2002) *Current practices and future directions in design within the construction sector: general considerations and industry perspectives*, July, T1 Construction Report No. E/IMRC/T1R-C/02/1, IMRC-EPSRC, LU.

Egan, J (1998) *Rethinking construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions. London: HMSO.

Egan, J (2002) *Accelerating change*, Report by the Strategic Forum for Construction, SFC.

European Commission (2006) *The PAXIS manual for innovation policy makers and practitioners, analysis and transfer of innovation tools, methodologies and policy*. Brussels: European Commission.

Flanagan, R, Ingram, I and Marsh, L (1998) *A bridge to the future: profitable construction for tomorrow's industry and its customers*. London: Thomas Telford.

Graves, A, Rowe, D and Sheath, D (1998) *Constructing the government client*. London: HMSO.

Green, S D (1998) The technocratic totalitarianism of construction process improvement: a critical perspective. *Engineering Construction and Architectural Management*, **5**(4), 376–86.

Gregory, M J and Deasley, P J (Ed.) (2002) *Distributed design issues in the aerospace, construction and product design sectors*: *global review*, August, T1 Report No. E/IMRC/T1R-G/02/1A, IMRC, Cranfield University.

HM Treasury (2000) *Public private partnerships: the government's approach*. London: TSO.

Land, G and Jarman, B (1993) *Breaking point and beyond*. San Francisco: HarperBusiness.

Langford, D and Murray, M (2003) *Construction reports 1944–98*. Oxford: Blackwell.

Latham, M (1994) *Constructing the team*, Final Report of the Government/Industry Review of Procurement and Contractual Arrangements in the UK Construction Industry. London: HMSO.

M4i (2000) *A commitment to people – our biggest asset*, Report from the Movement for Innovation's working group on Respect for People, November. London: M4i.

McCaffer, R and Edum-Fotwe, F T (2003) Construction in transition: where are we, and where could we be? Paper presented at the Second International Conference on Construction in the 21st Century (CITC-II) Sustainability and Innovation in Management and Technology, 10–12 December 2003, Hong Kong.

Mulgan, G (2006) The process of social innovation. *Innovations: Technology, Governance, Globalization*, **1**(2), 145–62.

Ofori, G (1994) Establishing construction economics as an academic discipline. *Construction Management and Economics*, **12**(4), 307–13.

Oke, A (2001) Making it happen: how to improve innovative capability in a service company. *Journal of Change Management*, **2**(3), 272–81.

Senge, P, Kleiner, A, Roberts, C, Ross, R, Roth, G and Smith, B (1999) *The dance of change: the challenges of sustaining information in learning organizations, a fifth discipline resource*. London: Nicholas Brearley.

Technology Foresight Panel on Construction (1995) *Progress through partnership*, 2, Report for the Office of Science and Technology. London: HMSO.

Tucker, R B (2002) *Driving growth through innovation*. Berrett-Koehler Publishers.

Turner, J (2006) The next innovation revolution: laying the groundwork for the United States. *Innovations: Technology, Governance, Globalization*, **1**(2), 123–44.

Winch, G M (2003) Models of manufacturing and the construction process: the genesis of re-engineering construction. *Building Research & Information*, **31**(2), 107–18.

Winch, G M (2006) Towards a theory of construction as production by projects. *Building Research and Information*, **34**(2), 164–74.

LEARNING TO KNOW AND KNOWING TO LEARN: DISCURSIVE PRACTICE AS KNOWLEDGE ENABLER

Christine Räisänen[1] and Sven Gunnarson

Building Economics and Management, Chalmers University of Technology, Sven Hultins gt 8, Gothenburg, SE-412 96, Sweden

An important challenge for the construction industry is the capture and sharing of enacted, context-specific knowledge and experience. Such knowledge is made up of both technical components and components dealing with communication, motivation and social interaction. To manage this ensemble, a new professional praxis needs to be developed. Drawing on learning theories, this paper focuses on a particular activity, the dialogue seminar, which supports collective meaning making. The cornerstones of a dialogue seminar are the modalities of reading, reflecting, writing and dialogue. Based on empirical examples from our research on dialogue seminars and on our own application of the approach in a continuation course for the construction industry, this paper argues that collective learning needs a structured praxis and a legitimate place and time in the organization.

Keywords: collective learning, construction industry, dialogue, professional knowledge, reflection.

INTRODUCTION

Today, new practices, increasingly sophisticated and demanding customers, growing competition and more complex product differentiation are putting pressure on construction companies to pay attention to learning and knowledge dissemination within and between building projects. Although the complex issues of knowledge management and learning have been widely researched over the past two decades, much of this research has been concentrated on developing comprehensive information technology repositories to ensure that knowledge is codified and disseminated, e.g. standards, regulations, governing principles and prescribed practices. This explicit knowledge forms the governing accounts of how the organization works, and in due course become ingrained into the organization’s structures, making it difficult to question and contest (Gabriel 2000).

However, while formal structures do serve as viable repositories for the accumulation and transfer of explicit knowledge, they cannot capture the enacted, context-specific practices of a workplace, nor can they ensure that the experiences acquired from one project may be used as a basis for judgement in future projects. While these formal repositories are valuable for novices, who are struggling to learn the organizational routines, they are less effective for the capture and sharing of new knowledge in the making and lessons learned among practitioners. Moreover, actors in construction projects, at least in Sweden, prefer verbal to written communication and are more

[1] christine.raisanen@chalmers.se

likely to seek information from co-workers than from written documents or the intranet (e.g. Gluch 2006; Styrhe *et al*. 2004). They consider their day-to-day activities as mainly consisting of immediate, situated solving of emergent problems and rely on their close co-workers as knowledge resources (Knauseder *et al*. forthcoming).

There is a lack of mechanisms to enable distributed construction organizations to collectively capture the dynamic professional know-how created through the ongoing discursive interplay between people involved in situated action in local contexts (Lave and Wenger 1991; Scollon 1996). This implicit or 'tacit' knowledge cannot be articulated or codified since it is intimately linked to individuals or group practices in the workplace (Nicolini *et al*. 2003; Gherardi 2001; Nonaka *et al*. 2001). Rather it is disseminated through communication such as the exchanges of 'war stories' between members of a community of practice (Fong 2005; Orr 1996). Explicit knowledge is supported by tacit knowledge, and it is this tacit underpinning that guides the user in situations where judgements need to be made. Tacit knowledge 'is the understanding that enables us to produce behaviour without thinking about it' (Isaacs 1999: 51). Learning does not only mean acquiring knowledge content, i.e. knowing that, but also understanding the contexts in which that knowledge applies e.g. knowing how, why and when. Answers to the latter questions are usually embedded in organizational routines, norms and ideologies, and are the main causes of organizational inertia manifested in the 'not invented here' syndrome.

Narratives and stories are effective vehicles for sharing experiences and highlighting contradictions. They can be a means of creating a common platform for communication and collective thinking (e.g. Boyce 1996; Gabriel 2000; James and Minnis 2004; Weick 1996). A variety of more or less structured methods have been developed to collect and disseminate organizational narratives, storytelling workshops (Abma 2003), the learning history (Jeffries *et al*.) and conversations (Isaacs 1999). Most of these methods concentrate on the modality of speech; the stories are retrospective reconstructions of situations (Weick 1996), which are then shared and discussed among participants. Although such reconstructions are valuable for making sense of organizational discourses and activities as well as for triggering new ideas, the modality of speech remains elusive.

The purpose of this paper is to explore the possibilities of a structured collective knowledge-creating and sharing praxis in which several modalities come into play – reading, reflecting, writing and conversing – and where several minds and voices are dialogically engaged. The method, called dialogue seminar, was collaboratively developed in-house by researchers and the managerial players of a complex systems-development firm (Göranzon *et al*. 2006). The first author of this paper studied the development process and the praxis to assess its potential for other fields. We have then adapted and tested the method on a number of continuation courses for managers and in-house project management courses (Räisänen and Gunnarson 2006) in the construction industry. We first briefly discuss some inherent contradictions that hinder collective learning. We then describe the dialogue seminar praxis in its original context. We then show how we adapted the praxis to an educational context. The paper ends with a discussion of the windows of opportunity that the dialogue seminar opens for collective meaning making in organizations.

ORGANIZATIONAL CONTRADICTIONS

Although knowledge management and learning are recognized as important issues at the strategic level of an organization, there remains an inherent resistance to deal with the underlying psycho-social and cultural factors that influence learning. The strong positivistic belief in measurement and the transparency of the data tends to result in a reductionist definition of knowledge, equating it with information; hence the over-belief in information technology as the solution. A realistic description of organizations in general – which we think also applies in construction organizations – is that depicted by Claxton (1999), which he calls the implementation mindset. These organizations are driven by technocratic views of rational efficiency grounded in ideologies of rationality, quick-wittedness, decisiveness, and being articulate and well informed. However, research in cognitive psychology, neuroscience and learning, among others, are suggesting evidence to the contrary, namely that creative thought processes are not linear, quick, logical and articulate, but rather hesitant, meandering, subject to multiple revisions and inner deliberations before being expressed (e.g. Claxton 1999). Thought processes are dynamic social phenomena. They are context-specific, drawing on individuals' past knowledge and experience, their assumptions and prejudices, and their assessment of the situation. In other words the nature of creative thinking is a 'soft' process that takes place on a tacit plane fed by social interaction and discourse.

Action and discourse are inherently interweaved and every discourse is linked to 'an entrenched action-net of alliances that facilitate translation and mobilization of knowledge and modes of knowing' (Gherardi and Nicolini (2003: 214). The analogies, metaphors and examples embedded in the discourses trigger associations, which enable interlocutors to conceptualize and articulate tacit knowledge. This in turn makes it easier to internalize and memorize the information for future use. Therefore, codified knowledge (e.g. data) will not produce action on its own; it has to be interpreted, internalized and enacted by people in situated practice (e.g. Lave and Wenger 1991). In our view, one of the main problems with collective and organizational learning is not a lack of capability at the individual or group level, but rather the lack of learning practices that enable the sharing of tacit knowledge and make learning relevant, stimulating and worthwhile. Fong (2005) showed how dialogue, such as feedback and storytelling across disciplinary borders in cross-disciplinary construction project teams created mutual understanding and enhanced the sharing of tacit knowledge.

Learning across organizational borders, disciplines or spheres of society is to-date neither much practised nor much researched. Yet, this kind of learning can provide a totally new and enlightening perspective on in-house problems. By telling the story of a systems development firm's transformation into a learning organization, we provide such an example and suggest how we may use some of the lessons learnt to enhance communication and learning in construction firms.

THE DEVELOPMENT OF A DIALOGIC PRAXIS

The setting

CS is a knowledge-intensive, project-based firm that develops integrated hardware and software solutions for embedded real-time systems. Within this area, the work tasks are varied, spanning several disciplines and specializations, such as systems design, software development, electronic engineering, process optimization and staff training. The company was founded in 1992 as an independent branch of a large corporation. Since then it has expanded rapidly (from six employees in 1992) to over 300 consultants in 2003 at 12 locations throughout Sweden. About 80% of the business is generated outside the corporate group, with clients from R&D departments in large and medium-size enterprises within automotive engineering, aerospace, defence, medicine, telecommunications and multimedia.

The background

With the rise of the information society, the market for complex systems design grew dramatically putting pressure on knowledge firms such as CS to seek a competitive edge through effective management of their intellectual capital. For CS it also became imperative to prevent their experts from being recruited by competing or client companies. Moreover, to maximize their knowledge capital, CS needed to ensure that individual knowledge and experience within the company were shared and used to generate new insights and knowledge.

Providing staff with explicit knowledge – knowing that – during their first few years in the company did not pose a problem; however, to stimulate and incite knowledge workers to engage in productive inquiry (Cook and Brown 2002) e.g. reflection about methods, tools and meanings used in their practice, was far more difficult. Management lacked the competence and experience to develop a method for productive inquiry that would encompass the whole company. The largest challenge was to change the deeply ingrained implementation mindset of the engineers. In a retrospective reflection on the company's struggle towards this end, the CEO commented:

> We realized [then] we needed to improve, but did not know what direction to take. Our questions kept circling around professional knowledge: What is it, how can it be developed and how is it transferred? […]

In a joint venture with researchers, CS embarked on a pilot project to explore the nature of experiential learning in a professional context; more specifically they wanted to understand the relationship obtaining between individual and organizational knowledge. The objective was to enhance knowledge in the firm by developing an institutionalized practice for intersubjective reflection concerning the nature of knowledge and the role of language in meaning making; in short the objective was to become a learning organization both in words and in deeds (Fock 2006).

The view that the researchers had of professional knowledge is that it is a complex interweaving of technical expertise, intuitive judgement and communicative sensitivity. These qualities are acquired through collaborative engagement that goes beyond the use of work descriptions and methods. To foster these qualities at CS, a prevalent and reductionist definition of knowledge – knowledge is equal to information, is acontextual, explicit and codifiable – had to be challenged. Moreover, the governing view that knowledge can be transferred by means of generalized rules, models and standards also needed to be questioned.

The endeavour

A pilot project was initiated in 1997 by a group of nine senior executives including the CEO and led by two researchers of work science. The goal of the project from the researchers' perspective was to shift the participants' inherently scientific epistemology of possession (individuals possess knowledge) towards an epistemology of practice (knowledge is generated through action in professional groups: Cook and

Brown 2002). The assumption was that to achieve this epistemological shift, scientific discourses and genres needed to be challenged and in part replaced by new constitutive meaning carriers generated through collective dialogue.

What CS wanted was to implement a method that would enhance the organization's collective knowledge, promote a holistic view of systems development, foster individual and group know-how and sense of judgement, encourage variation and creativity, and give the company a strong competitive edge. CS's ambition was to use the method in their interaction with their clients.

The pivot of the pilot project was language. Drawing on Wittgenstein's notion of language games (1983) and the dynamic, dialogic plasticity of meanings (Bakhtin 1986), the researchers strove to sensitize the group of nine to the intricate interrelationships between words and action, i.e. to enable the CS technical experts to internalize a wide variety of language games and understand the linkages between language, action and knowledge.

The method developed at CS was called the *dialogue seminar*. As the name indicates, the method is dialogic, relying on the active use of several genres and modalities: close reading, reflecting, personalizing, writing, listening, talking, performing and publishing. The dialogue seminar creates legitimate time and space for personalizing and sharing conversations, voicing alternative or contradictory stories, scrutinizing and discussing diverse meanings and perspectives on technical and social aspects of the organization's practices. It is a means 'thinking together' (Isaacs 1999). As one of the group of nine expresses it:

> A dialogue seminar is an environment for thought. [It] must foster the element of surprise and the unexpected, and allow diversity and disparate perspectives to fuel reflection and generate new, common, knowledge.

In the following section we briefly describe the method as designed for the purposes of CS.

The method

A typical dialogue seminar at CS is divided into three parts: pre-seminar, seminar and post-seminar. Each seminar is led by a senior knowledge worker well versed in the practice. He or she chooses a set of texts to base the seminar conversations on. These texts may concern specific problems within the area of systems development, but they may also be from entirely different fields. The chosen texts have different functions. They may be thematic, relating directly to the theme and problem area that the seminar has in focus; they may be analogous, describing other practices or problems in entirely different fields in order to create perspective; and they may be epistemological, conveying fundamental understanding, historical and epistemological, of a situation or practice.

Prior to the seminar the participants have to read the texts and are instructed to annotate as they read: i.e. to have a dialogue with the text. The associations, examples, analogies and contrasts triggered by the texts should then be personalized in individual narratives (essays). The participants are specifically asked to relate events and phenomena in the texts to their own experiences. In this preparatory part, the participants are engaged in three important activities: close reading, critical reflection and tapping into their own experience to bring forth what they did not know they knew.

In the dialogue seminar, each individual narrative is 'published'; it is read out loud by the author while the rest of the participants listen. Participants then reflect on what they have heard, first individually and then collectively. In this way, each reading generates reflection and dialogue on the action described. In this intersubjective exchange, different points of view confront each other and are merged, creating a powerful collective energy.

In the post-seminar phase, the records of all the new meanings (analogies and metaphors) generated in the collective dialogue and documented by the recorder are circulated and annotated by the seminar participants. The revised record and all the personal narratives are then made available to all CS employees, serving as organizational memory, consisting of novel associations and meanings specifically relevant to the CS context. These collectively generated new meanings serve to sharpen systems developers' sense of judgement by providing them with a reference for what the community of practice views as appropriate for a given situation.

The outcome

The primary task of the group of nine was to question the underlying assumptions built into established rules and models and to develop an architecture for systems design that consisted of tools and methods that were collectively created, supporting creative thought processes and facilitating communication and collaboration. In the pilot project, the group laid the groundwork for the continued change process within the organization by rewriting the organization and spreading their story in a jointly published anthology (Hoberg 1998) recording their transformation and their reflections. Since its publication, this text has been used as reading material in the first dialogue seminar attended by novices. It initiates them into the discursive practices of the organization through learning-by-doing rather than through top-down prescription. The concepts that are highlighted in this and the other texts read by novices are associated with social interaction, communication and collective meaning making for systems developers. In these texts examples, analogies and metaphors are widely used as mediating tools for productive enquiry as the following example demonstrates:

> We have to have a dialogue with the tool/technology. What can it achieve and what are its limitations? When it comes to new tools and methods we must have the possibility to practise before we start using them in real situations. We at CS often compare our practice to that in the theatre, with the staging of a performance. There is a huge difference; actors **practise – rehearse –** before they perform. Imagine how wonderful it would be if we could do the same thing in a system-development project. The project manager would be the director, who would not allow the programmers to work with 'real' coding until they have mastered all the tools and the method. We could run micro-increments of the project in order to practise and test the development model. (Essay by novice attending his first dialogue seminar)

In this short extract, we see how the novice struggles to appropriate the mediating tools of his profession as he reflects over the crucial importance of understanding the prescribed tools and the role of the manager. This reflection gave rise to several insights and illustrative oral stories from more experienced systems developers concerning the limitations of tools and methods, the qualities of leadership, the time constraints in projects, and the possibilities of building learning loops into work models.

The CS story is a good illustration of Cook and Brown's (2002) notion of knowing in action. The whiteboard becomes a metaphor for the dialogue seminar and at the same time its primary mediating tool. It consists of an empty landscape where individual and group knowledge, both tacit and explicit merge in the social action of generating a new genre: to whiteboard!

It took the group of nine a year to create the architecture for the new CS: they called this trial period 'the year of the architecture'. Since then, the dialogue seminar has become an institutionalized method for productive inquiry throughout the organization. All the new recruits are socialized into the method and it is also used as a tool for negotiating with clients. It is not within the scope of this paper to discuss CS's work with the dialogue seminar in greater detail, but it serves as an example of a successful attempt to change the mindset of an organization.

DIALOGUE SEMINARS FOR CONSTRUCTION

We have adapted the dialogue seminar in a variety of courses for actors involved in different sectors of the construction industry. Here we discuss the viability of the dialogue seminar to enhance collective thinking and learning for the industry. Since we used the same approach and procedure described above, we now focus on the outcome and possibilities provided by the approach.

Background and endeavour

The course entitled 'Effective knowledge management and project development' was divided into two parts. Each part consisted of three two-day modules, run as seminars rather than lectures. The modules in the first part, as the following titles describe, concern how to exploit intangible assets and resources in construction projects, i.e. M1: Balanced project psychology; M2: Situated communicative practice; and M3: Effective knowledge-management. The authors of this paper developed and ran modules two and three, the third as a dialogue seminar. (The last three modules deal with tangible assets, such as measurement tools, performance and profitability.) The course was the outcome of a joint initiative by industry and the university to provide practitioners with the opportunity for continued education. We have completed two full courses with 13 and 12 participants, respectively.

The purpose of the dialogue seminar was threefold: to test the method in a context of heterogeneous participants, to enable the synthesis and externalization of new knowledge acquired in the two previous modules, and to allow the participants to experience a new praxis through doing it. Reflecting on practice, as mentioned earlier, does not come naturally, especially not for practitioners schooled in an epistemology of technological determinism, and there is seldom sufficient time or space for reflection built into organizational and project work models. There is therefore a need to raise practitioners' awareness of the potential benefits from collective reflection during, as well as after, a project. We saw the dialogue seminar as a way of fostering participants both with method and tools, as well as the experience of moving from the implementation mindset to a processual mindset.

We chose one of each of the text types described above. The thematic text argued for the value of reflective writing as a tool for individual and collective reflection. The analogous text was a type of allegory describing the dilemma of the leader of a shipwrecked polar expedition consisting of Eskimos and Germans. The epistemological text probed the inherent contradictions between creativity and routine. They were given the same instructions as for the CS seminars. After the seminars, we collected all the stories and our own follow-up notes in a memory-book, which we then distributed to the participants.

All the participants, although reserved and sceptical of the writing task prior to the seminar, completed their essays and participated in the seminar. During the dialogue seminars, the participants never wanted for discussion topics. Each essay reading resulted in engrossing discussions and candid revelations. Some of the essays were personal; others depicted generic problems encountered in project management. The topics that the essays gave rise to differed in the two seminars owing to the different configurations of participants. In the first seminar, where the participants were all senior managers with similar disciplinary backgrounds, the topics clustered around four practical areas: the need for a change of attitude within the construction industry, the need for improved leadership development, the need for a holistic view of the building process, and the sector-specific problems such as certification and salaries. In this group, the energy in the discussions was generated by the participants' need to externalize their concerns and frustrations in terms of the future. The mutual recognition and sharing of these feelings as well as the identification of some of the causes created an understanding across professional borders, which hitherto seemed to be lacking.

The second group was composed of several participants from very different educational backgrounds, e.g. economists, engineers, lawyers, architects and from widely different professional spheres within construction e.g. academics, municipal officials and private sector managers. There were also relatively more women in this group than in the previous one and a wider age distribution. Another difference between the two groups was that group two was extremely verbal, which is fairly unusual in a Swedish context. In this group the topics clustered around abstract concepts such as the value of ideal representations (utopias), the multifaceted nature of listening, the advantages and disadvantages of knowledge and information, and types of learning and their effects. Although these topics may seem abstract, they were generated from some very concrete stories of personal adversities and gave rise to a variety of interesting insights into the whys and wherefores of some organizational norms and practices. Here the essays probed the causes and effects of individual actions and the nature of the lessons learned from these stories. The added perspectives from their peers contributed to a richer understanding in the group.

Illustrative examples

The distributed texts and previous modules were the springboard to help participants tap into their own stores of experience. The openings of some of the essays reflect this process:

> Sitting here and reading the texts many words buzzed around me: knowledge, openness, goal, purpose, definitions, limitations, client, complexity – and all the while the question why? Why do things function or why don't they function? We seek solutions and we create complex methods in order to make things work better the next time around. Even though we may know somehow, that with common sense we can go far. What is common sense?

Rhetorical questions were often used to introduce the topic and organize the argument, especially in the less personalized essays. Examples of some of these questions were: How much do project members need to know? or Who is the client? or What factors make some projects successful and others failures? or How and why do misunderstandings and misinterpretations arise? These questions may seem rather broad – and they are. The point is that they are seldom ventilated in the workplace. Instead they lie under the surface – as the causes of many problems – but are not sufficiently probed when solutions are suggested. These broad questions became the starting point for focused and personal opinions.

Although the essays were very different in terms of content, form and style, they all touched upon fundamental issues that were uppermost in the minds of the participants at this point in time. No one trivialized the task or the resulting conversations, and all the essays, probably because of their differences, elicited reactions. It is interesting to note here that everyone contributed to the conversations. Either they reflected in general terms on specific statements or they identified with examples in the texts, relating them to their own general experiences of projects or they countered with a personal example as corroboration or contrast.

Typically, personal essays could start like this.

> Once a long time ago … when *my world* was about to change. It happened in 1978 during my first week as team leader. I had just graduated as an engineer and was proud to be part of the building of one of the county's largest hospitals. I felt confident since I possessed experience from many summers' traineeship on building sites and felt I knew quite a lot about how things were done. My older brother, an experienced site manager, advised me: 'don't think you know everything about a building site; wait 10 years or so.' Yea, yea, I thought. *But what had he really said?!*

The essay goes on to describe how the young team leader provokes a head-on conflict with an older and experienced carpenter by criticizing him in public and giving him an order. The carpenter, known as the *golden hammer*, was the chosen leader of the carpentry group on site. He reacted violently to being insulted in front his 'guys'. He retaliated with a long and loud invective, ending by commanding the novice to: 'disappear into your office and shuffle your papers, and never appear on the site again!' The author was crestfallen and at a loss since he did not understand what had gone wrong. After all he had just been following the rules. When he later phoned his brother and told him that he was going to quit, his brother exclaimed: 'Had you already forgotten my advice or did you not understand what I meant?' The story ends with the author's reflections on the social dimensions and meanings of the word 'communication', a word that is broadly used and likewise broadly misused. This story and many like it gave rise to very intense discussions concerning emotions, attitudes and facing threats in the workplace. These are again issues that are seldom addressed other than behind closed doors.

The reading and writing exercises aimed at providing the participants with new ways of using these tools for thinking. Normally reading in the workplace is focused on content, which is then taken at face value. Likewise, writing in the workplace is a routine chore, where templates rule over both purpose and content. Reading the texts out loud aimed at demonstrating how differently we perceive a text when we read it silently to ourselves and when it is read out loud by the author, whose intonation, stance, tone and emphases bring life to even a seemingly boring text. Furthermore, this kind of reading is more likely to stick in a listener's memory. One common reflection from the participants was their surprise at the variation of styles and interpretations. The writers used different strategies to get their stories across. The following are a few examples.

Metaphors or images are effective ways of illustrating a point. Two metaphors, which became mottos for the groups were the ‘journey’ toward a goal and the ‘choice of path’. There was unanimous agreement that the project journey, process, was more important for learning than was the product. The choice of path became emblematic in many discussion concerning organizational changes and career paths within the construction industry.

Another strategy that was used in the essays was irony. For example one participant described the perfect meeting. This utopia exposed all the inadequacies of current meeting cultures and gave rise to a think-tank on what each individual’s responsibility could entail and how we could contribute to small changes in our own organizations.

Similes or analogies were probably the most common strategy, for example drawing on current sports events to discuss leadership and organizing. Moreover, many tapped into the analogy of the shipwrecked polar expedition to compare with their own chaotic situations. Another strategy is to draw on philosophical or theoretical examples. One such example was the use of Darwin’s evolution theory, which was used to show what happens when evolution is forced or rushed without preparation for change or time for adaptation.

The reactions from both groups during the follow-up were overwhelmingly positive. Besides being impressed by the stories and amazed that two pages of writing could contain so much of interest, they thought that the discussions were the richest learning activities. When we probed the reasons for this, they concluded that it was because the lessons learned were linked to specific individuals and situations. Moreover the discussion topics were generated by the groups and therefore felt to be far more relevant to any topics we would have imposed.

An interesting reflection was that the dialogue seminar enabled the participants to acquire knowledge and experience in a short time. This is an important insight since one of the arguments against using dialogue seminars in the workplace could be that it is far too time and resource consuming. This short-term perspective is thus overridden by the long-term benefits experienced by the participant. Several of them decided to try and adapt the approach to e.g. project planning or kick-off meetings. The most important reaction for us, which has further encouraged us to use the method in all our courses as well as in our research, is that the participants without exception were intellectually stimulated by the activity and genuinely enjoyed the activity.

CONCLUSIONS

In this paper we have shown that using a structured dialogical methodology, incorporating both oral and written modalities stimulates as well as facilitates a shift in mindset and attitude towards change in an organization. In our courses, we found that the dialogue seminar was a powerful tool to inspire participants to engage honestly in conversations and to share their personal views and experiences. The use of several modalities stimulated several senses simultaneously, which we feel resulted in an analytical rather than a cataloguing stance to the texts, their essays and the ensuing dialogues.

The different modalities also facilitated the externalization of tacit knowledge in the groups. The readings led to personal reflections and associations to personal experience of similar or contrasting events. The writing allowed the participants to visualize their ideas, examine and evaluate them. In the dialogue seminar, the sharing of individual narratives by the group generated innovative ways of dealing with common problems. On the social plane, the sharing of stories created coherence in the group as well as solidarity. Together, the group developed a common mode of communication that was in tune with the interests and affinities of that particular group. Each group shaped the implicit norms and sense of judgement, which could be called up as examples in future situations of uncertainty. The seminar thus provides a space for the orchestration of voices and sense making within a collective in an organization.

REFERENCES

Abma, T (2003) Learning by telling: storytelling workshops as an organizational learning intervention. *Management Learning*, **34**(2), 221–40.

Bahktin, M (1986) *Speech genres and other late essays*. Austin: University of Texas Press.

Boyce, M (1996) Organizational story and storytelling: a critical review. *Journal of Organizational Change Management*, **9**(5), 5–18.

Claxton, G (1999) *Hare brain, tortoise mind: why intelligence increases when you think less*. Hopewell, NJ: Ecco Press.

Cook, N and Brown, J S (2002) Bridging epistemologies: the generative dance between organizational knowledge and organizational knowing. *In*: S Little, P Quintas and T Ray (Eds.) *Managing knowledge.* London: Sage Publications.

Fong, P S W (2005) Building a knowledge-sharing culture in construction project teams. *In*: J Chimay, C Egbu and P Carillo (Eds.) *Knowledge management in construction*. London: Blackwell.

Gabriel, Y (2000) *Storytelling in organizations: facts, fictions, and fantasies.* Oxford: Oxford University Press.

Gherardi, S (2000) Practice-based theorizing on learning and knowing in organizations. *Organization*, **7**(8), 211–23.

Gherardi, S and Nicolini, D (2003) To transfer is to transform: the circulation of safety knowledge. *In*: D Nicolini, S Gherardi and D Yanow (Eds.) *Knowing in organizations.* New York: M E Sharpe.

Gluch, P (2006) *Building green: perspectives on environmental management in construction.* Göteborg: Chalmers University of Technology.

Göranzon, B, Hammarén, M and Ennals, R (2006) *Dialogue, skill and tacit knowledge.* London: John Wiley & Sons.

Göranzon, B and Hammarén, M (2006) The methodology of the dialogue seminar. *In*: B Göranzon, M Hammarén and R Ennals (Eds.) *Dialogue, skill and tacit knowledge.* London: John Wiley & Sons

Isaacs, W (1999) *Dialogue and the art of thinking together.* New York: Currency.

James, C and Minnis, W (2004) Organizational storytelling. *Business Horizons*, **47**(4), 23–32.

Jeffries, M, Eng, S and Lenke, R (2005) Evaluating an organization’s learning culture using learning histories. *In:* A S Kazi (Ed.) *Knowledge management in the construction industry: a sociotechnical perspective.* London: Idea Group Pub.

Knauseder, I, Josephson, P-E and Styhre, A (forthcoming) Learning capabilities for housing, service, and infrastructure project organisations. *Construction Management and Economics.*

Lave, J and Wenger, E (1991) *Situated learning: legitimate peripheral participation.* Cambridge: Cambridge University Press.

Nicolini, D, Gherardi, S and Yanow, D (2003) Toward a practice-based view of knowing and learning in organizations. *In*: D Nicolini, S Gherardi and D Yanow (Eds.) *Knowing in organizations.* New York: M E Sharpe.

Nonaka, I, Noboru, K and Ryoko, T (2001) Emergence of 'Ba'. *In*: I Nonaka and T Nishigushi (Eds.) *Knowledge emergence: social, technical, and evolutionary dimensions of knowledge creation.* Oxford: Oxford University Press.

Orr, J (1996) *Talking about machines: an ethnography of a modern job*. Ithaca, NY: Cornell University Press.

Räisänen, C and Gunnarson, S (2006) Pooling individual experiential narratives to enhance organisational learning. *In*: R Pietroforte, E De Angelis and F Polverino (Eds.) *Construction in the XXI century: local and global challenges*. Rome: Edizioni Scientifiche Italiane.

Scollon, R (1998) *Mediated discourse as social interaction*. Longman: London.

Styhre, A, Josephson, P-E and Knauseder, I (2004) Learning capabilities in organizational networks: case studies of six construction projects. *Construction Management and Economics*, **22**(9), 957–66.

Weick, K (1996) *Sensemaking in organizations*. Thousand Oaks, CA: Sage.

Wenger, E (1999) *Communities of practice: learning, meaning and identity*. Cambridge: Cambridge University Press.

Wittgenstein, L (1989/1953) *Philosophical investigations.* London: Blackwell.

THE FINANCING ISSUE: THE CASE OF INNOVATIVE FIRMS FROM THE BUILDING AND CONSTRUCTION INDUSTRY

Frederic Bougrain[1]

Département économie et sciences humaines, Centre Scientifique et Technique du Bâtiment (CSTB), 4, avenue du Recteur Poincaré, 75782 Paris CEDEX 16, France

Entrepreneurs who innovate are supposed to face financial constraints. The aim of the paper is to check this assertion for innovative building and construction firms. The analysis draws upon statistical data and case studies made of about 50 firms less than five years old that have been highlighted by the French weekly construction magazine "*Le Moniteur*". It shows that entrepreneurs face some financial constraints when they intend to launch innovations. It also indicates that new innovative firms are able to benefit from the support of private investors and large companies.

Keywords: innovation, newly created firms, financing, SMEs.

INTRODUCTION

According to the European Commission, "access to finance remains a major concern for businesses, including innovative SMEs. Innovative and R&D-intensive businesses often have difficulties in obtaining finance in the stages between demonstrating a new technology, process, product or service and exploiting it commercially. Compared with its main competitors, the market for finances for-innovative companies from the pre-seed to expansion stages in Europe is still underdeveloped. Better access to equity and quasi-equity for more mature innovative SMEs is also needed for 'follow-on' investment to help businesses reach their full potential, bring their products and services to the market, and continue funding their research" (European Commission 2005: 12).

This conclusion is confirmed by the data collected for the fourth Community Innovation Survey by the statistical service of the French Department of Industry. (The fourth Community Innovation Survey (CIS4) was launched in France in 2005. Collected information concerned corporate innovative behaviour during the period 2002–2004. About 25,000 French firms employing more than 10 employees received the postal survey.)

A total of 41% of French innovating firms quoted the lack of appropriate forms of finance and the costs of innovation as the main barrier to innovation (SESSI 2006). The lack of adequate knowledge (qualified employees, knowledge about technology and markets, difficulties to find cooperative partners) was ranked second and considered as a barrier by 26% innovative firms.

The study also demonstrates that firms employing less than 250 people are more financially constrained than larger ones. Similar results were found by Harhoff (1998)

[1]f.bougrain@cstb.fr

in Germany. Lack of bank loans and equity capital was the main obstacle to innovation. Similarly in the USA, Himmelberg and Petersen (1994) noticed that self-financing was the main resources invested in R&D by the 179 high-tech SMEs from their sample. Finally, in the Netherlands, the lack of financial funds was the main criterion that differentiates SMEs from their larger counterparts.

The financial issue appears even more important for newly created companies. These firms also lack self-financing capacity, but they cannot cushion the risk associated with the development of the innovation whereas established firms can rely on their day-to-day businesses.

The building and construction industry is often perceived as a laggard for innovation compared with other industries. The fragmentation of the industry, the procurement process mainly based on tendered price, the high number of small firms and the conservatism of employees of the building site are often put forward to explain this situation. Paradoxically, the financial issue is rarely presented as a constraint in the empirical literature.

The innovation research field in the building and construction industry has lead to a growing number of articles during the last few years. However, there is a lack of empirical studies in the field of financing of innovation. Therefore, the aim of this paper is to focus on the financing issue. The analysis will be restricted to newly created companies.

The goal will be twofold: the first is to examine whether entrepreneurs who created a new company based on an innovation project, encountered financial difficulties in the first years following their creation. The second is to identify which financial sources (internal resources, debt and external equity) companies tend to favour to develop their business.

The first part is based on a literature survey. It intends to provide arguments to answer the following questions: To what extent are innovative projects constrained by financial obstacles? The second part examines the characteristics of the innovation process along the supply chain of production. The aim is to establish a link between the financing issues, the actors and the nature of the innovation process. The third part draws upon case studies made of about 50 firms less than five years old that have been highlighted by the French weekly construction magazine “*Le Moniteur*”. Information was published every week between 2002 and 2005. It concerns the business sector of the firm, its capital structure, its year of creation, the number of employees and the background of the founder(s) (usually the manager(s) and owner(s)) of the firm. This part details which financial source is favoured and how the lack of financial funds hinders the development of the firms.

INNOVATION AND FINANCING: SOME THEORITICAL ELEMENTS

Uncertainty and innovation

“Innovation is a quest into the unknown. It involves searching and the probing and reprobing of technological as well as market opportunities” (Teece 1996: 194).

Innovation projects have to deal with three types of uncertainty (Freeman 1989):

1. Technical uncertainty is linked to “problem-solving feature of innovative activities” (Dosi 1990: 303). The solutions of innovation-related problems are

always challenged and the set of solutions is never known in advance. New technical states are discovered during the innovation process and vary according to opportunities and incentives. In some sectors such as pharmacy, it is even necessary to invest large sum of money before being able to assess the value of the initial idea. Therefore, delays and lags are not perfectly mastered. Associated costs may increase and jeopardise the project. This uncertainty, which is very high at the beginning of the life cycle of a product, can be reduced through tests and trials. But the feasibility of a project is just one element of a success. The innovation has also to be viable at a marketing level.

2. Market uncertainty refers to the commercial achievement of a viable product or process. Potential uses and demand are often highly unpredictable and the firm has almost no ability to control these elements. Moreover, external elements may modify the initial conditions that prevailed when the project was launched. New competitors may appear; consumers' tastes may evolve.
3. Uncertainty is also linked to business cycles. "In a mature, established industry the risk of the firm's assets is very likely determined by the fundamental riskiness of the firm's line of business" (Wedig 1990: 297). According to Wedig, the systematic risk attached to R&D projects is higher for small firm than for large ones. It is reasonable to assume that newly created companies face even greater risks. Most of these firms rely on a single product; they have no track record and cannot provide collateral to investors.

The uncertainty decreases when a project moves downstream and is close to final launch while the need for fresh money increases. The commercialisation stage requires investing much more financial and human resources than the development programme. For high tech sectors, it is often assumed that for every euro spent at the R&D level, ten will be necessary to bring the product into production and about 100 will be required to bring it to the market (Chabbal 1995).

The uncertainty is even reinforced by asymmetric information and moral hazard problems.

Asymmetric information and innovation

In the financing of innovation, the asymmetric information problem refers to the fact that managers usually have better information about the characteristics of their innovative projects than private investors. Consequently, lenders who cannot distinguish good and bad projects will propose a high-risk premium to all potential investors to compensate for risk default. Therefore, firms with sound projects will not stay on the market.

Reducing information asymmetry is quite problematic when one deals with innovation. Indeed firms may have interest not to disclose the characteristics of their projects for strategic reasons (Kay 1988). By revealing their innovative ideas, entrepreneurs face the risk that potential competitors benefit from their project. This problem is enhanced when inventor-entrepreneurs cannot rely on strong property rights to protect invention from imitation: "While this problem is somewhat softened when there is good patent protection, most non-industrial providers of funds are going to need technical experts to evaluate the technology, in which the risk of leakage remains" (Teece 1996: 210).

Asymmetric information problems are stronger for small businesses (Ang 1991). They are not forced to produce verifiable information. Therefore, it is more expensive for potential investors to collect information and to monitor the firm. Moreover, small businesses may have greater difficulties to send credible signs to the financing market.

These difficulties for private investors to appreciate the quality of innovative projects are enlarged by moral hazard problems.

Moral hazard and innovation
Potential investors have not only to appreciate the quality of innovative projects; they also have to monitor the behaviour of the entrepreneurs once the loan is afforded. Moral hazard problem refers to the fact that managers usually control the allocation of the funds while the investment effort is unobservable to the investor. Entrepreneurs have a tendency to put their venture's interests first during the first years following the creation of the firm. Investors are likely to have lower optimism. To avoid shirking behaviour and ex-post opportunism investors, they may require greater protection that will increase both direct and indirect costs of borrowing: "Direct costs of borrowing include such items as interests rate and monitoring costs; indirect costs include restrictive covenants, personal guarantees, and equity participation" (Brophy and Shulman 1993: 66).

Because of asymmetric information and moral hazard problems, risk adverse investors such as bank are likely to be reluctant to finance innovative projects with uncertain outcomes.

The financial constraints may even be much stronger for newly created businesses. Most of them rely on a single product. They also have a high debt-equity ratio and they are not able to provide strong collateral to minimise the risks taken by investors.

INNOVATION IN THE CONSTRUCTION SECTOR: THE FINANCING ISSUE

Some characteristics of the innovation process in the construction industry
The construction sector is too heterogeneous to be lumped into a single category. Firms' positions along the value-added supply chain affect their innovative strategy. Material suppliers, manufacturers of equipment, contractors, facility managers, etc., are likely to follow different patterns of innovation (the analysis is limited to these four actors that are among the most important in the industry).

Pavitt (1984), who was the first to put ahead the existence of sectoral patterns of technical change, categorised general contractors as "suppliers dominated firms". Firms from this category devote few resources to R&D. They focus their innovative activities on processes. "Most innovations come from suppliers of equipment and materials, although in some cases large customers and government-financed research and extension services also make a contribution" (Pavitt 1984: 356).

Material suppliers belong either to "large scale producers" (these firms are scale-intensive and devote a very high proportion of their resources to cost-reducing process innovation) or to "science-based firms" (internal R&D and scientific developments carried out in public research centres and universities, constitute their main sources of innovation. These firms do not limit their innovative activities to their sector of origin since they produce a very strong proportion of innovations used in other sectors).

Special foundations contractors, manufacturers of building components and equipments can be considered as "specialised suppliers". Their competitiveness rests on their specific know-how and their capacity to develop reliable products and to respond continuously to users' needs. Opportunities for innovation do not result only from in-house R&D but from close and complementary relationship established with customers.

Firms involved in the management and maintenance of the buildings tend to follow the pattern of services companies described by Sunbo (1998) and Djellal and Gallouj (1999). Most of the time innovative services do not come from an R&D department but from marketing department and transversal project groups. Innovations are also often co-produced with the end user.

Innovation and the financial constraint in the construction sector

Articles dedicated to innovation in the building and construction industry have benefited from a growing interest in the last few years. Paradoxically the field of financing of innovation has rarely been examined. Most studies focused on the financing of projects, which appear to be one of the main issues for the industry.

Elements from the empirical and theoretical literature speak for a financial constraint while some others do not.

Most innovations developed by contractors are made at the job site and do not require a high amount of financial resources. They are often developed in the course of a construction project. A dominant part concerns the organisation. They "are emphatically not 'R&D projects' in any formal sense" (Slaughter 1993: 87). In these cases, financing is not an issue.

Most material suppliers that spend a high amount of R&D are owned by large groups quoted on the stock exchange. They have access to international financial markets. Financing, *per se*, is not an issue. Because of their broad portfolio of businesses, the unpredictable results of innovative projects are mitigated. Therefore, private investors are not discouraged to support these firms. Then financing innovation may become an issue within the firm and between competing business units.

The building and construction industry is often perceived as a mature industry with a reputation for resistance to innovation and change. An empirical study focusing on the financial behaviour of craftsmen revealed that banks usually consider that the industry is less risky than others (Observatoire des PME 2005). The growth of the sector for the last five years is perceived as positive.

However, several arguments also indicate that the building and construction industry do not depart from the general trend and is financially constrained.

The fourth Community Innovation Survey (SESSI 2006) indicates that financial factors were considered as a barrier by about 43.6% of French innovative construction companies (39.4% of the firms surveyed declared that they were innovative between 2002 and 2004 (new products, process, organisation and market). Innovative products represented about 12% of the turnover of these firms in 2004; 27% of them modified the organisation of their activity; 54.8% carried out R&D between 2002 and 2004). The lack of competences, marketing factors and the lack of incentives respectively only concerns 31%, 30.3% and 13.3% of the firms. Moreover, 19% of non-innovative firms did not innovate because of the financial constraints.

This lack of appropriate forms of finance is stronger for small firms than for larger ones: 46.5% of small firms considered it as a barrier while there were only 16.6% of firms with more than 250 employees. These difficulties lead firms either to seriously delay their innovative projects (28.3% of the innovative firms of the sample) or to abandon them (16.2% of the firms). Larger companies are also affected (24.7% of them abandoned at least one innovative project between 2002 and 2004; 34.5% had to delay at least one project over the same period).

However, one of the limits of this national enquiry is to present construction as a homogeneous activity. As presented before, innovation patterns and constraints strongly differ among the actors of the value-added supply chain.

An ongoing research project indicates that contractors devote fewer resources to R&D and innovative activities than manufacturers. However, in some cases, when innovations are turned to commercial products, processes or services, funding might become an issue for contractors.

Manufacturers of building components and equipments do not need to rely on the most recent scientific knowledge. Their size is quite small compare with material suppliers. They have small R&D laboratory and design office to deal with the development of new products/processes. Therefore, they are still subject to lags and uncertainty, which are a source of financial constraints.

Newly created companies of the building and construction industry that mostly base their activities on a single innovative project probably do not follow the general pattern of innovation. To examine this case, the paper ends with an empirical study that draws upon case studies made of about 50 firms from the building and construction industry with less than five years old.

THE FINANCIAL CONSTRAINT OF NEWLY CREATED FIRMS FROM THE BUILDING AND CONSTRUCTION INDUSTRY

Between 2001 and 2006, the French weekly construction magazine “Le Moniteur” published detailed information about 80 newly created companies (the empirical study is limited to 50 cases. The next version of the paper will integrate all business stories. Moreover, some interviews will be carried out to get more qualitative information). These companies were less than five years old at the time of the publication. Their creation was based on a certain innovation.

Most information was published in 2003 and 2004 (more than 55 cases). Each article with about 450 words provided details on the business sector, the capital structure of the firm, the year of creation, the number of employees and the background of the founder(s) (usually the manager(s) and owner(s)) of the firm.

For the purpose of this study, it was necessary to classify each article in a common framework. Five categories were identified:

1. Contractors.
2. Manufacturer.
3. Consultant (companies that sell their specific know-how – e.g. a company selling diagnosis for asbestos, lead, etc.).
4. New services based on information and communication technologies.
5. Civil engineering.

Information concerning the number of employees and the source of finance for innovation were also retained to categorise each newly created company.

Three sources of finance were identified:

1. Public subsidies (such as zero interest loans, public grants, etc.).
2. Support of an investment fund: In this case, the private investor owns a minority part of the equity of the firm.
3. Support of a large firm.

Table 1 exposed the sources of finance according to the activity of the firms.

Table 1: Sources of finance according to the activity of new created firms

Activity	**Number of employees**			**Public subsidies**		**Support of an investment fund**		**Support of a large company**	
	<10	**10–19**	**20–25**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**
Construction techniques	3	1	0	1	3	0	4	0	4
Contractor (site process)	8	0	2	1	9	0	10	0	10
Manufacturer	4	2	0	1	5	2	4	2	4
Consultant	5	2	0	1	6	0	7	1	6
ICT	10	2	0	4	8	2	10	2	10
Civil engineering	10	1	0	4	7	1	10	3	8
Total	40	8	2	12	38	5	45	8	42

All these companies are very small: 80% employ less than 10 employees.

The manager is the majority shareholder in 48 cases. In 24% of the cases, firms have received some kinds of public subsidies (e.g. financial aids, free rent). This indicates that the public institutional framework dedicated to support innovation and business creators is quite well organised.

Investment funds are involved in only 10% of the projects. They tend to focus their investment in ICT and civil engineering projects.

This may result either from the strategy of the creator or from the attitude of the private investors:

- Creators usually look for the independence of their company. Most of them do not intend to attract private investors who may latter on take the control of the firm. The entrepreneurs' own resources and those of friends and family often constitute the starting equity.
- Private investors such as venture capital financiers tend to focus their investments on a limited number of sectors (Hall 2005). Venture capital investors usually target their investment in industry with high growth perspectives. They also intend to monitor the creator and to provide advice based on their experiences. They expect capital gains at the time of exit. These elements are supposed to reduce asymmetric information and moral hazard problems.

  The building and construction industry does not belong to the sectors that attract most of the investors. In 2005, building and construction attracted only 6% of the funds invested by private capital investors. It represented 2% of the files (AFIC 2005). (Biotechnology and the medical sector received 7% of the funds (16% of the files); the computer industry, 8% but 23% of the files;

telecommunication, 12% and 7% of the files; industrial goods and services, 18% of the funds and 10% of the files.)

Large companies appear as one of the main support of new firms (e.g. as a client or as an investor). The eight cases mainly concerned promising innovation. SMEs are characterised as being flexible and respond more quickly than large firms to external changing circumstances (Rizzoni 1994). By promoting new ventures, large firms that are considered more bureaucratic and tend to favour exploitation over exploration have access to complementary expertise. They also keep an eye open for new technology and equipment. The investments of large firms are a form of trade: funds and/or access to market against technical expertise. ("I am inclined to regard the early stage innovative disabilities of large size as serious and propose the following hypothesis : An efficient procedure by which to introduce new products is for the initial development and market testing to be performed by independent investors and small firms (perhaps new entrants) in an industry, the successful developments then to be acquired, possibly through licensing or merger, for subsequent marketing by a large multidivision enterprise…Put differently, a division of effort between the new product innovation process on the one hand, and the management of proven resources on the other may well be efficient" (Williamson 1975: 205–6).)

Among the firm of this sample, one considered that the lack of financial funds hindered its development. Two other were looking for private investors who had knowledge about the industry. This result appears quite contradictory with the national survey (uncertainty is supposed to be much stronger for newly created and innovative firms). Some reasons may explain this result:

- Many new firms that are working in services do not need as much financial resources as manufacturers.
- Entrepreneurs who start a business have the ability to receive several subsidies during their first year of activity. Moreover, for the first three years, they do not pay taxes.
- There is also probably a selection bias: most firms selected by the weekly magazine were among the leading start-ups in their field.

CONCLUSION

The financing issue for newly created firms and innovation has benefited from a limited attention of researchers working in the field of building and construction. The arguments developed in this paper intend to present this issue.

The study indicates that innovative firms from the industry do not depart from other sectors. They also perceive the financial factor as the main barrier to innovation.

Newly created companies that present growth prospects seem to receive more support from private investors or large firms than traditional firms (such as contractors).

This study also shows that the reputation of the building and construction industry, which is often perceived as a laggard for innovation compare with other industries, is not justified.

REFERENCES

AFIC and PricewaterhouseCoopers (2005) *Rapport sur l'activité du capital investissement en France*. Paris: Association Française des Investisseurs en Capital.

Ang, J S (1991) Small business uniqueness and the theory of financial management. The *Journal of Small Business Finance*, **1**(2), 1–13.

Brophy, D and Shulman, J (1993) Financial factors which stimulate innovation. *Entrepreneurship Theory and Practice,* **winter**, 61–75.

Chabbal, R (1995) *Le système financier Français face à l'investissement d'innovation*. Paris: La Documentation Française.

Djellal F. and F. Gallouj (1999) Innovation dans les services: les premiers résultats d'une enquête postale exploratoire. *In:* ANRT (Ed.) *L'innovation dans les services – Une invitation à l'insurrection intellectuelle*. Paris: Economica.

Dosi, G (1990) Finance, innovation and industrial change. *Journal of Economic Behavior and Organization*, **13**(3), 299–319.

European Commission (2005) Implementing the community Lisbon programme **-** More research and innovation **-** investing for growth and employment: a common approach. Communication from the commission to the council, the European parliament, the European economic and social committee and the committee of the regions, sec(2005) 1253, October.

Freeman, C (1989) *The economics of industrial innovation*. 2Ed. London: Frances Pinter.

Hall, B H (2005), The financing of innovation. *In:* S. Shane (Ed.) *Blackwell Handbook of Technology and Innovation Management*. Oxford: Blackwell Publishers Ltd.

Harhoff, D (1998) Are there financing constraints for R&D and investment in German manufacturing firms? *Annales d'Economie et de Statistique*, **49/50**, 421–56.

Himmelberg, C P and Petersen, B C (1994) R&D and internal finance: a panel study of small firms in high-tech industries. *The Review of Economics and Statistics*, **76**(1), 38–51.

Kay, N (1988) The R&D function: corporate strategy and structure. *In:* G. Dosi, C. Freeman, R. Nelson, G. Silverberg and L. Soete (Eds.) *Technical change and economic theory*. London: Pinter Publishers.

Observatoire des PME (1995) Entreprises artisanales du bâtiment – Pratiques bancaires et besoins de financement. *Regards sur les PME*, **7**.

Pavitt, K (1984) Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy*, **13**(6), 343–73.

Rizzoni, A. (1994) Technology and organisation in small firms: an interpretative framework, *Revue d'Economie Industrielle*, **67**, 135–55.

SESSI (2006), Un quart des entreprises innovent. *Le 4 Pages*, **222**, August.

Sundbo, J (1998) *The organisation of innovation in services*. Roskilde: Roskilde University Press.

Teece, D J (1996) Firm organization, industrial structure, and technological innovation. *Journal of Economic Behavior and Organization*, **31**(2), 193–224.

Wedig, G J (1990) How risky is R and D? A financial approach. *The Review of Economics and Statistics*, **72**(2), 296–303.

Williamson, O (1975) *Markets and hierarchies: Antitrust analysis and implications*. New York: The Free Press.

COMPETING ON INNOVATION IN A LOCATION CENTRIC SECTOR: A STUDY OF MALAYSIAN HOUSING DEVELOPERS IN INDIA, CAMBODIA AND SOUTH AFRICA

Ahmed Awil[1], Abdul Aziz and Abdul Rashid

School of Housing, Building and Planning, Universiti Sains Malaysia,Penang 11800, Malaysia

We report on the internationalization activities of Malaysian housing developers in three countries: India, Cambodia and South Africa. Activities associated with housing development have generally been locally centred, with production, design and consumption all being undertaken locally. Therefore housing developers have generally been engaged in location-bound competition. Competition among developers has generally been between local firms based on the location-specific practices. Such practices limited the activities of housing development firms to engage such activities within a certain geographic spread, with most firms competing locally, a few firms nationally and in some rare cases internationally. Yet, recent changes characterized by economic liberalization, housing reforms and increasing urbanization rates have transformed the housing development sector. This study reports on the way Malaysian housing developers have leveraged their activities in Malaysia into foreign locations through the leveraging of their competitive advantages. Housing development activities by developers from one country with financing from another country coupled with a contractor from another country and the purchase by non-local residents have characterized such changes. This study found that Malaysian housing developers were competitive in the development of integrated townships, golf resorts and high-end condominiums projects. Additionally innovation-based design, introduction of an industrialized and time-bound construction process and innovative marketing and financing deals were the other important features that differentiated Malaysian housing developers from their local competitors.

Keywords: housing development, innovation, internationalization, Malaysia.

INTRODUCTION

Like construction, housing is an immobile product that is undertaken for local consumption and is susceptible to the vagaries of the general economic environment. The notion of housing development we will assume to constitute the development of housing projects by business organizations for profit and, following the laws of supply and demand, the production may exceed or meet the needs of the market depending on the suitability of the project to the needs of the local populace (this may include expatriates or if investment laws allow foreign buyers for investment purposes). As such any production will be local in nature while the producers may be either local or foreign depending on the prevailing investment laws of the country.

The housing sector has changed in the past 50 years, during which many of the developing nations gained independence. Since then there have been gradual changes

[1] awil7@yahoo.com

in the laws of the housing industry. In the first period since independence the provision of housing has been considered as an obligation by the state to its citizens, therefore there was a proliferation of state agencies that were entrusted with the provision of housing to the populace. Governments have a strong interest in the performance of the housing sector. Good housing policies lead to better social stability (ODPM 2005) and are also used for managing macroeconomic growth (World Bank 1993). Over a period of time owing to factors like rising population, higher rates of urbanization and stagnant economies there has been reorganization of the housing industry in that private enterprises started participating and in due time were considered as an integral part of the provision of housing. The World Bank in 1993 advised governments to abandon their role as producers of housing and instead act as regulators of the market and adopt enabling policies to facilitate the participation of private sector in the housing sector (World Bank 1993). Since then there has been further reorganization of the local economies brought about by globalization and liberalization with governments realizing the increased need to allow the participation of foreign capital and firms in the local economy.

Most of the literature on international housing development is dominated by two streams of research; those studies dealing with the issues of cross-border portfolio investments (McAllister 1999; Worzala 1994) and those studies of housing sectors and policies for a given number of countries (Walker and McKinnel 1994; Doling 1999). Other studies have also dealt with the engagement of firms in international housing development but are focused on explaining motivations of the management and direct investment in a particular location. Jiang *et al.* (1998) investigated foreign investments in the Chinese real estate industry and found that direct investments into the local firms or outright purchase of real estate was driven by underdeveloped Chinese capital markets and as means of investment in a high growth market that offered above normal rates of return. This paper discusses the internationalization of the housing developers from two perspectives. First, it focuses only on innovation practices introduced into host markets; secondly, the discussion is based on experiences of Malaysian housing developers. The findings presented here are a part of a large study on the internationalization of Malaysian housing developers.

HOUSING DEVELOPMENT SECTOR

The housing sector is crucial in the economies of many countries and contributes to between 2% and 8% of the gross national product; the flow of associated housing services contributes another 5–10% (World Bank 1993). The impact of housing investments can be estimated from a look at the linkages between housing and related industries that is estimated from 269 industries (Karnad 2004) to 600 (Bestani and Klein 2004). The housing sector is also connected to the broader economy through a number of different circuits – the real, fiscal and financial sides of the economy. Investments in housing have long been understood to be an important tool for political stability, economic development and socio-economic up-liftment (Hollander 1963). Housing investments are also used at times to ‘pump prime’ the economy in order to overcome recessions. Davis and Heathcote (2005) in a study of the real estate sector (with data from 1948 to 2001) in the United States found that residential developments lead the economic cycle while non-residential developments lag the economic cycle. Again Green (1997) utilizing data from 1959 to 1992 finds that residential investments cause higher GDP growth rates while non-residential investments are caused by higher GDP rates.

The effects of the housing sector on the economy are at three levels: real effects associated with investment output, employment and prices. Financial effects are those associated with the financing of housing and related residential infrastructure, while fiscal effects are those associated with taxation and subsidization of housing (World Bank 1993: 34). Also institutional arrangements in the housing and mortgage markets play an important role not just in overall economic efficiency but also in managing economic shocks (Catte *et al.* 2004). Similarly, employment in the residential construction industry, which comprises 1–3% of the economically active population in developing countries, is associated with employment in other industries in the same ratios; one additional job in the residential construction sector gives rise to two other jobs (World Bank 1993).

Housing is a non-innovative industry and has a poor record in introducing innovative design and production, with firms not competing on innovation (Ball 1999; Barker 2004). The housing industry is less technologically intensive than many industries (Ball 1999), therefore there is less technological superiority between local and foreign firms and as such there are no ownership advantages that can accrue to housing developers if they seek to undertake internationalization. Yet, there has been an increase in the number of housing developers engaging in internationalization. Innovation as it is understood in this paper is a process of piecemeal improvements in the development by the stakeholders to the process (Ball 1999: 13). The following sections of the paper will detail the reasons why foreign housing developers are able to compete with local developers.

INTERNATIONAL HOUSING DEVELOPMENT

Changes in the dynamics of national economies, liberalization of markets, improvements in transportation and communication and ease of movement of capital have changed the previous assumptions that differentiated markets into domestic and international (Martin 2003). These changes have been evident since the late 1990s in the Asia Pacific region where liberalization of markets and higher rates of urbanization emerged allowing the participation of foreign firms to undertake international housing development initially for consumption by foreign or expatriate personnel and later for the domestic populace. These transformations in economies have mostly been evident in the Asia Pacific region since the early 1990s, and there has been an increasing role for foreign housing developers in those countries that have experienced economic liberalization, high urbanization rates and reforms in the housing sector. These housing developers have been primarily from this region, owing to the fact that the pace of housing development increases with increases in economic development (World Bank 1993).

Not all countries and locations that have had experience in developing a successful housing development sector have had any involvement with international housing developers. This arises due to three interacting features that are continually in a state of flux and determine whether there will be international housing development in a particular country. These three forces may be named as:

1. host government housing policies;
2. local housing industry;
3. international firms' initiatives.

These three factors determine whether there will be participation by international housing developers in a particular location. Taking the first factor of host government polices, this determines the general direction and growth that a particular nation undergoes and whether there will be any foreign direct investment or participation by foreign housing developers in the housing industry. The second factor encapsulates the status of the local housing industry and whether it is of sufficient technological or development advancement. If it is lacking in such critical inputs then there will be possibility of the engagement of international housing developers. The third factor of international firms' initiatives determines whether a particular firm is orientated towards engagement in international housing development. Where there is less concern about opportunities in international markets there will be fewer initiatives and therefore less engagement by the firm. In locations like India, China and Vietnam, and to a large extent Cambodia and South Africa, there has been a large infusion of foreign capital in the form of foreign direct investments. These investments have in turn created a demand, from both the local consumers and foreigners resident there, for new housing developments that meet their requirements, a demand also created by the rising affluence of the local populace. Both nations previously practised centrally planned economies where the workforce received subsidized housing courtesy of their employers. But owing to liberalization in their economies there has been upsurge in the demand and nature of housing that the local developers were unable to satisfy. This in turn called for two types of involvement; first, provision of skills and knowledge of the development process and secondly, the need to input capital into the local housing sector.

Malaysian housing developers have been active in Malaysia since the colonial era. Since then they have grown and their growth has been helped both by increases in population and urbanization. The Malaysian urban population increased from 4.6 million to 12.8 million between 1975 and the year 2000. To accommodate such a large size of population, new townships and extensive infrastructure had to be developed, with the government encouraging private developers to take a lead role. Malaysian housing developers also gained from astute planning and housing policies that enhanced and managed the growth of the housing sector. The housing sector in Malaysia has benefited from this relationship and the result has been Malaysia having some of the highest rates of home ownership in the world (UN Habitat 1998). Malaysian developers have been aided in the undertaking of such large developments by factors such as Malaysia's stable economic environment; provision of affordable loans by the banks; and a mature housing policy in practice in Malaysia which is known as the 'sell and build' concept, whereby housing developers are able to utilize the capital of housing buyers and thereby reduce any risks. Possession of large tracts of land (most developers initially were plantation owners) enabled developers to develop land stage by stage so as to test the viability of the development. These factors thereby increased the capabilities of Malaysian housing developers by enabling them to accumulate resources such as capital, development knowledge and experienced personnel.

Such advantages and level of advancement were not the sole preserve of Malaysian housing developers, but were also experienced by other developers from Singapore and Hong Kong. Owing to the limited land size and population, developers from the city states of Hong Kong and Singapore were motivated to internationalize their activities much earlier than Malaysian developers; in the case of Hong Kong developers extended to China in the mid-1980s and Singaporean developers in the early 1990s. The competitive advantages that these developers had over the local Chinese developers were expertise in the management of the development process, financial prowess and their introduction of advanced construction methods that enabled them to introduce innovative products and reduce the construction time. Yet, developers from Singapore or Hong Kong are not typical developers who have an interest in undertaking development as a viable means of business. Hong Kong developers have an incentive to integrate their activities with Hong Kong, given the fact that Hong Kong is integrated with China, logically allowing them to enhance their activities to a location that has the same cultural and linguistic affinities. Singaporean developers on the other hand are either private entities that are encouraged or led in their internationalization by the state, or the housing development firm is a majority state-owned enterprise, called a ‘government-linked company’. Housing developers like Keppel and Capitaland are examples of government linked companies undertaking internationalization. Doling (1999) discusses the housing sector in the little tiger economies (Singapore, Hong Kong and South Korea) as a state controlling the nature of development (owing to the fact that the majority of the land is state owned in Hong Kong and Singapore and state acquired for residential development in South Korea). Other factors like construction and consumption are market oriented and are within the discretion of the developer.

RESEARCH METHOD

This section presents an overview of the method used for data collection and analysis for this paper. A mixed-method approach was identified as a suitable means of locating the competitive advantages that Malaysian housing developers possessed. This approach was necessitated by the need to collect both quantitative data on the housing developers and a qualitative section that covers the internationalization of housing developers from their initial motives to their experiences. A total of 33 housing developers were identified through a combination of snowballing technique and a review of the publications in business and news media. Of that number eight housing developers responded to the questionnaire section of the study, while six of the eight developers consented to taking part in case studies detailing their internationalization. Subsequent cross-checking with industry professionals confirmed that it is only those eight developers who responded to the questionnaire to have actually undertaken internationalization, while the rest made announcements of their intention to internationalize or signed memoranda of understandings with foreign developers/partners. Data were collected through a questionnaire for the quantitative section and through interviews and site visits to consenting developers coupled with secondary data for the qualitative section. The questionnaire was pre-tested through a pilot study involving academicians, housing development professionals and the president of the housing developers association. Responding developers were asked to rate internationalization factors on a five-point Likert scale. Space limitations preclude us from presenting detailed case studies of the housing developers’ activities. Additionally, confidentiality assured to respondents prevents disclosure of their identities.

RESULTS

We will be presenting below the competitive advantages possessed by Malaysian housing developers vis-à-vis local developers in their internationalization. Further, competitive advantages have been divided into three factors: ownership, locational and internalization advantages (identified from Dunning 1980, 1988). Dunning argued that for firms to internationalize they need to possess superior ownership advantages vis-à-vis local firms (processes or products); to realize these advantages in particular locations; and to organize these through internal firm structures. We report here only on the ownership advantages. Ownership advantages have further been broken down into two: ownership advantages emanating from advantages intrinsic to the firm and advantages accrued due to country ownership of the firm. Country-specific advantages are developed from close interaction between developers, suppliers, government and buyers (Porter 1990). In this paper we will limit reporting to the ownership advantages intrinsic to the housing developers. Firm ownership advantages emanate from resources within control of the firm. Resources are inputs into the firm's production process that include: capital (its borrowing capacity and ability to generate internal funds); equipment (sophistication of its plant and equipment); skills of employees (formal reporting structure, planning, controlling and coordinating systems); and patents (trade marks, copyrights and trade secrets) (Hoskisson *et al.* 2004). Resources that a firm possesses enable it to exercise its ownership advantages in undertaking internationalization. Resources and related activities possessed by a firm have an important influence on the propensity of firms to internationalize (Chatterjee and Wernerfelt 1991; Ramanujam and Varadarajan 1989). However, not all resources controlled and owned by the firm constitute a source of sustained competitive advantage (Porter 1985). Therefore, for resources to be able to provide competitive advantage they must have the following characteristics: they must be valuable, rare, non-substitutable and difficult to imitate by rival firms (Barney 1991).

Table 1: Firm ownership advantages (advantages intrinsic to the firm)

Ownership advantages	N	Mean	Rank	Std. deviation	Level of importance
Understanding foreign market potential	8	4.50	1	0.535	Very imp.
Large financial capital	8	4.25	2	0.463	Imp.
Superior and innovative property development skills	8	4.13	3	0.354	Imp.
HQ–overseas coordination	8	4.00	4	0.535	Imp.
Firm's name and image	8	4.00	4	0.535	Imp.
Relationship with local and central authorities in host country	8	3.88	5	0.835	Imp.
Business relationship with host country firms	8	3.88	5	0.835	Imp.
Extensive experience and capable workforce	8	3.87	6	0.354	Imp.
Part of a larger group	8	3.87	6	1.126	Imp.
Business relationship with Malaysian firms	8	3.63	7	0.518	Imp.
Previous international expertise	8	3.63	7	0.518	Imp.

Notations used: means 1.0 to less than 1.49 = unimportant, 1.5–2.49 = little importance, 2.5–3.49 = moderately important, 3.5–4.49 = important, from 4.5–5.0 = very important.

Housing developers report their top three ownership competencies as their advantages accruing from their understanding of opportunities in foreign markets, their financial capital and their skills in superior and innovative property developments (see Table 1). In the first instance knowledge of housing markets and emerging opportunities is important in aligning a firm's competencies with potential opportunities. The liberalization and reforms in the housing sectors of India, China, Vietnam, Cambodia and South Africa for different reasons created a number of opportunities for foreign housing developers. Malaysian housing developers were the first movers into India, Cambodia and South Africa. Secondly, the possession of significant financial capital is both an important competitive advantage over local developers (more so in discussion) and a legal necessity (in India, foreign developers need to invest in a minimum of US$5 million in a joint venture and US$10 million in a wholly owned subsidiary) in the undertaking of international developments. In the housing development sector, larger developers are able to borrow capital at lower interest rates, spread risks over a wider area and offer different types of developments that cater for different levels of income (Ball 2003). Thirdly, experience and knowledge of innovative housing development activities over local developers helped Malaysian housing developers in their internationalization.

India

India, one of the world's largest countries, has recently undergone a period of economic reform since liberalization of the economy in 1991. Among the changes include the government privatization of most of the state-owned enterprises and increasing participation of the private sector in almost all the sectors of the economy. The pace of liberalization picked up after the initial period and the participation of foreign enterprises in the local scene was allowed gradually. Among the sectors that have benefited from this liberalization is housing development. In the year 2002, during the budget proposal the go ahead was given to the participation by foreign enterprises in the Indian housing sector. This decision stemmed from two roots: first, the need to increase foreign direct investment into India, which was lacking in comparison to China (Jiang *et al.* 1998 report that one-third of all foreign direct investment in China was real estate related); and secondly to raise the expertise level and process knowledge of the local housing sector through collaboration or competition with foreign developers. In India, there has been a recent increase in the announcements of Malaysian housing developers who have an interest in carrying out housing development. When the data collection phase of the study was being carried out in mid-2005, there was only one Malaysian housing developer who was active in India. This developer, Developer A, was the first international housing developer to initiate an integrated township project in India. Developer A is part of larger group that has interests apart from property development in construction, plantation and industries.

Developer A has taken advantage of its previous experience in India as a contractor to diversify into property development. The possession of a construction arm is an important advantage in India. First, the developer is able to ensure better quality of its developments and secondly, the developer is able to assure buyers of the completion date. Indian house buyers were previously let down by both the quality of developments and the delay in handing over properties after the due date. With these promises being made at the initial stages and the highlighting of the housing developer's experience in Malaysia, house buyers were confident of the ability of the developer to deliver on these promises. Other innovative practices delivered to the Indian buyers include concealed utility services and a clubhouse.

Cambodia

Cambodia was plagued by a protracted civil war between 1970 and 1992. The civil war was settled at a peace accord in 1992, followed by general elections supervised by the United Nations. The prolonged civil war in Cambodia caused serious disruption to the local economy. The dire economic situation inhibited the development of local banks and associated financing for domestic mortgages. The local housing developers lacked the professional expertise needed to utilize the development knowledge of foreign developers. The changing political situation created a favourable environment for both domestic and foreign firms. Among the favourable changes is that Cambodia is a member of Association of Southeast Asian Nations (ASEAN) and has a free trade agreement with the United States in the export of textiles. Because of these favourable factors there has been an increase in inward investment in the setting up of textile garment factories for export to the United States. Additionally, there has been a return of Cambodian diaspora to the homeland. The combination of incoming foreign investments and diaspora has necessitated provision of new housing developments for residential or commercial purposes. Two Malaysian developers ventured into Cambodia, the first in 2004 and the second in 2005; Developers B and C.

Developer B's Cambodian development comprises 172 units of two-storey detached villas and 30 townhouses, giving a total of 202 units. Phase one, comprising 70 villas, has recorded 50% sales since its launch (in mid-2005). A prominent marketing strategy of Developer B is to sell to Cambodian house buyers the concept of having an integrated community that is being introduced for the first time into Cambodia. Cambodian housing is dominated by mixed use developments that have office/shop lots on the ground floor with the upper floor used as family accommodation. The image of Malaysia as a country that has developed in economic terms and has a successful housing sector has also helped in the marketing and selling of properties to Cambodian house buyers. The development by the Malaysian developer is both the single largest housing development and also the first integrated development in Cambodia. The development features:

- gated community with perimeter fencing and guardhouse;
- practical and modern design;
- beautiful landscaped park and elegant roads lined with trees;
- family clubhouse facilities.

Among the new features in housing development introduced into the Cambodian market is the concept of 'house without renovation'. This concept originates from the Malaysian developer's attempt to coordinate the needs of the house buyer well before construction (during the design stage) so that the buyer has no need to alter his house after handing over. The negotiation between the buyer and developer for the buyer's design changes are negotiated well in advance so as to incorporate such needs of the buyer into the house design. In Cambodia, the authors observed during field visits that even new houses that have been built are undergoing renovation, which is indicative of either the poor quality of the development or the inadequacy of the design to accommodate the individual needs of the buyers.

Developer C has introduced the concept of mixed development into Cambodia for the first time. Previously, Cambodian developments were divided into residential or commercial developments. Additionally commercial developments were either office blocks or shop lots. The commercial part of the development introduces the concept of versatility to potential buyers, by allowing them to combine office lots, buy one level or combine shop lots with the office lots, providing buyers a multiplicity of choices in a modern setting with facilities that are contemporary in nature. With the introduction of the shop-cum-office lots concept to Cambodia Developer C has accrued the first mover advantage for its development.

South Africa

Since the end of the apartheid era in South Africa there have been marked changes in the political and economic situations. Principally these have been the lifting of sanctions, multi-party elections and economic opportunities for the majority population. Malaysian investors have been among the earliest into South Africa, encouraged by the previous government of Dr Mahathir Mohamed (see Awil and Abdul-Aziz (2005) for a detailed discussion on government role in the internationalization of housing developers). In the post-apartheid era Malaysian investors were the second largest investors in South Africa after the United States.

Three Malaysian housing developers began operating in South Africa in the immediate post-apartheid era. We report here on the activities of one developer, Developer C, who internationalized into South Africa in 1996 and completed the last phase of its development in 2006. This developer has developed a distinct niche in Malaysia as a property developer with innovative practices that focus on developing a country-style living. This developer in partnership with a local developer jointly developed a golf estate, the first in South Africa, in the vicinity of Pretoria (the political capital). Among the earliest innovations undertaken by Developer C included limiting the financial risks that potential house buyers were exposed to by capping the interest rates at 15% for the first two years after house purchase (this was in the period following the apartheid era, a period of high and rising interest rates). This attracted those house buyers for whom interest rates were an inhibiting factor. Additionally, the guarded residential golf estate was the first such estate in South Africa.

CONCLUSION

The housing sector has generally been a sector where foreign capital and foreign developers have played a minimal role. Housing developers from the Asia Pacific region have been experiencing a general increase in their internationalization into countries in the region. The three countries discussed above have different housing sectors, yet the three of them have initiated policies that have attracted foreign developers. The experiences of Malaysian housing developers in three countries have shown that it is possible to compete in location-centric sectors, through the introduction of innovative development practices. Though the local developers are knowledgeable and experienced in the local scene, yet their advantages can be surmounted by the ability of foreign developers to utilize their foreign capital coupled with the introduction of innovative development practices. Malaysian developers were competitive in those types of developments of which they had experience at home such as golf estates, high-end condominiums and integrated townships. As the three countries discussed above are developing countries, the findings are specific to developing countries.

REFERENCES

Awil, A U and Abdul-Aziz, A R (2005) The role of government in the internationalisation of Malaysian housing developers. Paper presented at Queensland University of Technology Research Week, 4–8 July 2005.

Ball, M (1999) Chasing a snail: innovation and house building firms strategies. *Housing Studies*, **14**(1), 9–22.

Ball, M (2003) Markets and the structure of the house building industry: an international perspective. *Urban Studies*, **40**(5–6), 897–916.

Barker, K (2004) *Review of housing supply: delivering stability; securing our future housing needs*, Final report recommendations. London: HMSO.

Barney, J (1991) Firm resources and sustained competitive advantage. *Journal of Management*, **17**(1), 99–120.

Bestani, R and Klein, J (2004) Housing finance in Asia. Asian Development Bank Working Paper, available at www.adb.org/PrivateSector/Finance/Housing-Asia.pdf (accessed 12 May 2004).

Catte, P, Girouard, N, Price, R and Andre, C (2004) Housing markets, wealth and the business cycle. OECD Working Paper No. 394.

Chatterjee, S and Wernerfelt, B (1991) The link between resources and type of diversification: theory and evidence. *Strategic Management Journal*, **12**(3), 33–48.

Davis, M and Heathcote, J (2005) Housing and the business cycle. *International Economic Review*, **46**(3), 751–84.

Doling, J (1999) Housing policies and the little tigers: how do they compare with other industrialised countries? *Housing Studies*, **14**(2), 229–50.

Dunning, J H (1980) Towards an eclectic theory of international production: some empirical tests. *Journal of International Business Studies*, **11**(1), 9–31.

Dunning, J H (1988) The eclectic paradigm of international production: a restatement and some possible extensions. *Journal of International Business Studies*, **19**(1), 1–31.

Green, R K (1997) Follow the leader: how changes in the residential and non-residential investment changes predict changes in GDP. *Real Estate Economics*, **25**(2), 253–70.

Hollander, E D (1963) *Relationship between housing and economic development*, Study of international housing, Subcommittee on housing: committee on banking and currency, United States Senate. Washington, DC: US Government Printing Office.

Hoskisson, R, Hitt, M A and Ireland, R D (2004) *Competing for advantage*. Cincinnati, OH: South Western.

Jiang, D, Jinghan, J and Isaac, D (1998) The effect of foreign investment on the real estate industry in China. *Urban Studies*, **35**(1), 2101–10.

Karnad, R S (2004) Housing finance and the economy: regional trends: South Asia perspectives. Paper presented at the 25th World Congress of International Union for Housing Finance, 23–24 June, Brussels, available at www.hdfc.com/pdf/HDFC-IUHF04.pdf (accessed 22 July 2004).

Martin, W (2003) Developing countries changing participation in world trade. *World Bank Research Observer*, **18**(2), 187–203.

McAllister, P (1999) Globalisation, integration and commercial property: evidence from the UK. *Journal of Property Investment and Finance*, **17**(1), 8–26.

ODPM (2005) *Housing policy: an overview*. London: Office of the Deputy Prime Minister and HM Treasury.

Porter, M (1985) *Competitive advantage*. New York: Free Press.

Porter, M (1990) *The competitive advantage of nations*. London: Macmillan Press.

Ramanujam, V and Varadarajan, P (1989) Research on corporate diversification: a synthesis. *Strategic Management Journal*, **10**, 523–51.

UN Habitat (1998) Global urban observatory. Home ownership data for Malaysia, available www.unhabitat.org/programmes/guo/data_hsdb4.asp (accessed on 13 February 2006).

Walker, A and McKinnel, K (1994) Economic reforms and the future for real estate in the People's Republic of China. *Journal of Property Valuation and Investment*, **13**(5), 39–49.

World Bank (1993) *Housing: enabling markets to work*. Washington, DC: World Bank.

Worzala, E (1994) Overseas property investments: how are they perceived by the institutional investors? *Journal of Property Valuation and Investment*, **12**(3), 31–53.

SOCIAL NETWORK ANALYSIS: A ROBUST METHODOLOGY TO EVALUATE KNOWLEDGE CREATION CAPABILITY AND ABSORPTIVE CAPACITY

Era Kurul,[1] Noriko Otsuka and Andrea Colantonio

Real Estate & Construction, Oxford Brookes University, Oxford, OX3 0BP, UK

'Knowledge creation capability' and 'absorptive capacity' are argued to be the main sources of competitive advantage in the UK construction industry. They are inextricably linked with one of the ingredients of 'social capital, i.e. accessibility to resources by individuals. Even so, the current discourse on managing knowledge does not pay due cognisance to these aspects of integrated project teams. This research primarily aimed at exploring the interrelationships between these concepts at the team level and testing the robustness of Social Network Analysis (SNA) as a methodological approach to establishing the structural features of social capital that promote or demote knowledge creation capability and absorptive capacity, mainly by augmenting the accessibility to resources by individuals. Semi-structured interviews with key members of two project teams were interpreted through the combined use of SNA and content analysis. Here the SNA results are discussed. The main practice-related finding is that project managers (PMs) are the knowledge brokers in project teams with unique advantages in accessing external knowledge and controlling knowledge flows within their teams. Methodologically, SNA was shown to have the potential to be developed into a robust tool to assessing accessibility to resources by individuals and to assessing innovation capability of project teams once the methodological approach of this project is developed enough to measuring resources as assets and to evaluating the outcomes of mobilizing these resources.

Keywords: integrated team, knowledge management, methodology, social systems.

INTRODUCTION

The knowledge management (KM) paradigm has evolved considerably since the 1990s when it emerged as a novel thrust in organizational performance research. Its domination by the 'asset capitalization' perspective has been counterbalanced by the acknowledgement of informal knowledge processes, such as the ability to source, transfer and create knowledge, as strategic capabilities for gaining competitive advantage (Fong 2003; Kess and Haapasalo 2002; Roth 2003; Reagans and McEvily 2003; Quintas *et al.* 2003; Sharkie 2003). Within this context, any functional unit's ability to recognize the value of *external* knowledge, to assimilate it and to apply it to commercial ends, i.e. its 'absorptive capacity' (Cohen and Levinthal 1990), has become critical in gaining competitive advantage.

The above evolution has been hand in hand with the emergence of "the second knowledge perspective", which perceives knowledge "as a set of shared beliefs that are constructed through social interactions and embedded within the social contexts in

[1] ekurul@brookes.ac.uk

which they are created" (Fong 2003). New knowledge is created through 'a series of transformations, by which standard resources, which are available in open markets [or contained within the project teams], are used and combined within the organizational context in order to produce [competences and] capabilities' (competences and capabilities (unlike resources) are unique to each organization, and so are the sources of competitive advantage (Grant 1991)) (Ciborra and Andreu 2001; Roth 2003; Lang 2001; Lank 1997)..

Social interactions play an important role in this transformation process, which is generally undertaken by intra-organizational project teams within the UK construction industry. These interactions are contained within the social networks of teams and facilitated by the linkages between their members. As a result, exploring how these linkages influence each member's opportunity to access the resources that are embedded in his/her social network becomes a key step towards understanding a construction firm's role as a knowledge creator.

Bourdieu's (1986) conceptualization of social capital is appropriate for this exploration as it acknowledges both the social structure itself and the networks and the resources that people can access through that structure. Lin (1999) details Bourdieu's concept by introducing the "three ingredients of social capital: resources embedded in a social structure; accessibility to such social resources by individuals; and use or mobilization of such social resources by individuals in purposive actions." These ingredients resonate with Nahapiet and Ghoshal's (1998) three dimensions of social capital: structural, relational and cognitive, and they are inter-related. Among these relationships the structural and positional variations are of special interest in terms of the differential distribution of accessibility between members of a network. Therefore, this paper focuses on the structural dimension. Such a focus would also be instrumental in assessing the robustness of Social Network Analysis (SNA) as a methodological approach to establishing the network features that increase or decrease a member's accessibility to the embedded resources. As a result, it may become possible to use SNA for measuring absorptive capacity.

Structural dimension of social capital is concerned with the network of relations that are embedded in the structure of any social group. It purely relates to 'the configuration of linkages between people or units'. These linkages are the main channels through which knowledge, specifically tacit knowledge, flows within project teams. They play an important part in defining the extent of a team's absorptive capacity, which depends not only on its interface with the external environment but also on the transfer of knowledge within and across project teams (Cohen and Levinthal, 1990; Bresnen *et al*. 2003). Moreover, these linkages create opportunities to exchange and combine existing knowledge. As such, they are the bases of one of the three conditions of knowledge creation (Groshal and Moran 1996).

A DISCUSSION ON METHODOLOGY

This research was undertaken in the context of two qualitative case studies. This approach matched well with the limited amount of existing knowledge in this study area and the consequent exploratory nature of this research. Moreover, it resonated with the context-specificity of knowledge and knowledge processes, which calls for a methodological approach, such as case studies, that would facilitate their study in their real-life context (Yin 1994).

One inter-organizational project team in each of the two industrial partners to this research project provided the context for the field study. Case Study One (CS1) was the project team (PT1) building an office block in the City of London for one of the UK's largest development companies. The project team (PT2) that was refurbishing a laboratory/office facility for a multi-national pharmaceutical company was our second case study (CS2). In both cases, the clients and the main contractors had established working relationships for more than a decade. In both instances, the contractors had single-point responsibility. Thus, the emergent project teams were *integrated*.

A combination of Social Network Analysis (SNA) and content analysis was the main methodology used in this research. Here the discussion only focuses on SNA as content analysis is out of the scope of this paper. At the lowest level of analysis, SNA relies on data on the quantitative features of the relations, e.g. frequency of contact, between the nodes that form a network (Freeman 1992) (nodes can be people, departments or whole institutions. In the context of this research, the nodes of each social network were members of the project teams that were studied). SNA was considered to be a robust methodology as it would facilitate the exploration of the structural features of a social network through the analysis of 'relational data' (Scott 2000), as well as providing a collection of metrics to determine how the project teams used the resources embedded in their networks to source knowledge and advice (Wasserman and Faust 1994). It was considered to be particularly suited to project teams that were studied because they were temporary coalitions bound together by flows of information and materials (Pryke and Pearson 2006; Winch 2002). Furthermore, it was anticipated that SNA would facilitate simple quantitative measures and the visualization of the teams' networks, paving the way to very useful discussions amongst their members. It would thus enable limited deployment of action research. It had been acknowledged that SNA alone would not be adequate to explore the qualitative features of the relationships between the nodes despite these advantages. Therefore, content analysis was used at a later stage of the research project to systematically analyse the textual data on these features, and thus to address "the problem of relational content" (Burt and Schott 1992; please see Data Collection section below for a discussion).

(Some sub-sections of this section are based on Kurul *et al*. (2007).)

Sampling

Both case studies were identified in collaboration with senior staff of industrial partners according to the procurement method, project stage at the time of the first field-study, size, complexity, novelty of the project, and the anticipated levels of collaboration that the client and the project team would demonstrate. Subsequently, the key participants to the research project were selected from both teams in collaboration with the Project Director (or equivalent) as they were in a position to identify the key team members that were critical for knowledge creation at the project level. This approach also enabled the research team to determine the boundaries of the networks that it was going to study based on the "significant" issue under consideration, i.e. criticality for knowledge creation within the team. In this respect, Scott's (2000) "reputational approach" to identifying the network boundary was followed. Despite the inherent potential bias in this selection process, the research team deemed this approach to be necessary to gain the project teams' trust and to secure their full support. Given this, anticipated levels of co-operation at the project level gained prominence over the global representativeness of the deliberately small research sample. However, methodologically acceptable levels of representativeness were achieved in the sampling of the interviewees from the broader project team. Interviewees were selected such that all the stakeholder groups that were involved in the projects were represented.

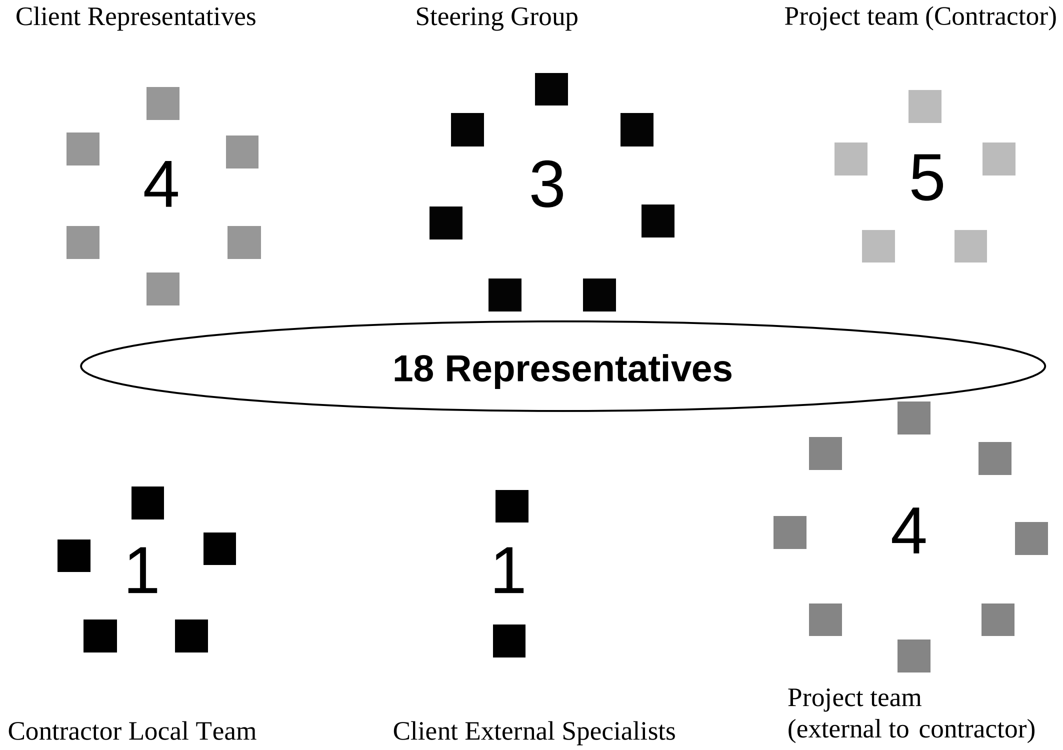


Figure 1: Sampling

Figure 1 illustrates this point. It shows the interviewee sampling for CS2 in terms of the sizes of different groups of stakeholders (represented by the number of boxes in each cluster) and the number of interviewees chosen from each group (integers given at the centre of each cluster). This approach yielded an interviewee sample of 20 and 18 team members respectively for CS1 and CS2.

Data collection

The research project entailed two fieldwork periods during which data was collected through semi-structured interviews with each participant. The questions for the first round of interviews were based on our conceptual framework and ensuing literature review; and were piloted on the Project Directors (PDs) (or equivalent). Similarly, the second round of interview questions were devised after feedback sessions with the teams and tested with both PDs. During the two field study periods, the post-doctoral research assistants (RAs) were based in the project offices in order to observe the interaction between interviewees in their natural working environment and to substantiate, to a limited extent, the validity of the interview data.

The main means of relational data collection were “name generator” questions that the interviewees answered during the first fieldwork (Burt 1997; Lin 1999; Marsden 1990). These questions are given in Table 1. Questions 1 and 2 were mainly concerned with the generic contact made with members of the project team, while Questions 3 and 4 related to sourcing knowledge and advice from colleagues within the team or outside it. These two sets of questions were designed to establish whether different groups of people were contacted for generic issues and for sourcing knowledge and advice. Question 5 further explored this issue, while Question 6 aimed at understanding whether team members were investing in sustaining their social networks at an informal level outside their working environments.

Table 1: Name generator questions

1.	How often do you contact the people within the project team?
2.	Could you map your contact lines on the project team diagram?
3.	Who do you contact first when you have a problem and why that person? In what capacity do you know him (or her)?
4.	Who do you contact first when you want to find out something or need some knowledge/advice? Why do you contact that person? In what capacity do you know him (or her)?
5.	Would you ask for the same advice to someone else? If yes, can you tell me why?
6.	Do you also spend some of your free time with the above people?

The main potential shortcoming of the above list of questions is that they assume a common understanding of what ‘knowledge’ is and that the interviewees can readily distinguish between, for example, knowledge and information. The research design aimed at overcoming this shortcoming by introducing the distinction between knowledge and information during the interviews. However, it is still possible that some of the respondents may have used these terms interchangeably, and thus they may have referred to information sourcing relations instead of knowledge sourcing relationships.

In this context, we also face “the problem of relational content” which represents the context of other activities within which the knowledge interaction between two nodes took place (Burt 1997). One way of overcoming this problem was to ask redundant questions in order to establish whether the interviewees had variable tendencies for their knowledge interactions. This was achieved to a limited extent by including Question 4 as a redundant question for Question 3. Another issue with the relational content was that the interviewees had to decide which of their activities were problem solving activities and what they sought was knowledge. Moreover, social network models that were used assumed that each node interpreted their knowledge interaction activities in the same way as other interviewees did. Once again, the semi-structured interview set up allowed for establishing what a problem-solving activity was. The interpretative differences between interviewees could have been addressed by asking each interviewee to describe the problem-solving activity that s/he was referring to in some detail. Unfortunately, this opportunity was overseen at the time of this study.

Another issue with the data collected is that the interviewees were asked to recall the names of the people that they sourced knowledge and information from. Marsden (1990) points out that recall data is biased towards stronger links. As a result, nodes that form the end of weaker links may have been omitted from the dataset. In the main, such possible omissions could not have had a major influence on the findings “egocentric data” gathered from sampled individuals was analysed, and hence the generated names which fell outside the research sample and data associated with them was not analysed.

Data analysis

Raw relational data was tabulated in databases and analysed through SNA by using InFlow (InFlow is the social network analysis software package that was used in this research). Tabulation was based on the names that emerged in response to the “name generator questions” (see Table 1) and the frequency of the contact for knowledge and advice sourcing that was cited by the interviewees, i.e. daily, weekly, monthly and rarely. Hence, we analysed "egocentric network data" for the ties surrounding the sampled individuals (Marsden 1990).

This tabulated data was used to draw network maps of the project teams and to calculate SNA metrics. One-way and two-way network maps could be drawn but only two-way maps were analysed. One-way maps included all the nodes which were referred to during the interviews, i.e. A, who was in our interviewee sample, referred to a knowledge and advice sourcing relation to X who was not in our sample. Hence, nodes that were not in our interviewee sample became part of the one-way network maps, which demonstrated that the actual boundary of the network goes well beyond that which we identified by using the reputational approach. Conversely, two-way maps only comprised of the nodes that we interviewed. In all cases but one, there were reciprocal links between the nodes, i.e. A referred to B in terms of a knowledge and advice sourcing relation, and B referred to A in the same context.

The decision to analyse only the two-way maps was taken for three main reasons. First, at the subject level, the two-way knowledge and information exchange interactions are regarded to be most critical for finding new ways of doing things, i.e. knowledge creation. Second, in the methodological context, there is "the fundamental need for at least two persons and at least one connection of some special sort between them" (Wallace 1996, quoted in Freeman 1992). The one-way maps indicated that there was a relationship between the nodes but it was not possible to get both nodes to mutually acknowledge the presence of this relationship and to verify its knowledge sourcing nature. This third reason was a barrier, which was a consequence of the resource constraints on this research.

Many different types of SNA metrics could have been produced through the analysis. The SNA metrics given in Table 2 were produced and interpreted for the purposes of this. The choice of these metrics was based on the review of SNA literature (e.g. Mizruchi and Potts 1998; Otte and Rousseau 2002; Reagans and McEvily 2003) and its previous applications (e.g. Loosemore 1998; Pryke 2004). This review enabled the research team to identify *density*, *degree centrality*, *closeness centrality* and *betweeness centrality* as the main metrics to be examined in order to explore the relationship between the structural dimension of social capital, stimulators of absorptive capacity and of knowledge creation. Short definitions of these metrics and a very brief overview of their potential influence on knowledge creation and sharing processes are given in Table 2. Additional factors such as *network reach* were also taken into account in the analysis in the light of their usefulness to understand the relationships between these stimulators and the cognitive and relational dimensions of social capital. The latter were subsequently investigated in greater depth by using content analysis, which is outside the scope of this paper.

Table 2: SNA indices vs. KC capability & AC

Density measures the connectivity of nodes (interviewees) to others in the network. It is a representation of the number of existing connections as a percentage of all theoretically possible connections. Density values above 0.50 (or 50%) indicates that there is risk of communication and/or information overload in the network(Krebs and Holley no date)
Degree Centrality provides an indication of the extent to which a node is connected to its immediate environment. Denotes a node's ability to communicate directly with others in the network, in other words their communication activity (Freeman 1979). Also, it denotes an individual's opportunities to access resources (Sparrowe *et al.* 2001) and is a significant predictor of his/her involvement in innovation (Ibarra 1993)
Closeness Centrality represents "the extent to which an actor can reach a large number of other factors in a small number of steps" (Mizruchi and Potts 1998). Nodes with high closeness centrality have the ability to reach large numbers of nodes while they rely on a minimum number of intermediaries (Freeman 1979). They can avoid the control of others, and are efficient as they can reach all other actors in the shortest number of steps (Nohria and Eccles 1992)
Betweeness Centrality reflects a node's potential to control other nodes by controlling and filtering the information flow between them (Loosemore 1998; Sparrowe *et al*. 2001). Nodes with high betweenness centralities could play 'brokerage' or 'gatekeeper' roles
Network Reach is a measure of the length of information paths between nodes. The key paths in networks are 1 and 2 steps, and on rare occasions 3 steps (Burt 1992, Friedkin 1983). "Horizon of observability" indicates the maximum path length, beyond which people are unlikely to be aware of other people's roles and work (Friedkin 1983)

The results of these analyses were presented to the relevant project team in two workshops. These workshops not only provided the participants an opportunity to express their views on the research findings but also enabled the research team to incorporate some degree of action research as they facilitated discussions within the project teams about their knowledge creation and sharing practices.

MAIN SUBJECT-SPECIFIC RESULTS

A detailed discussion on the interpretation of the above metrics is outside the scope of this paper. Readers interested in such elaboration could refer to Kurul *et al.* (2006, 2007). Below is a brief overview of the main results of this research project.

The main findings suggest that project team configurations have a high level of influence on the network structure, which influences both knowledge creation capability and absorptive capacity of project teams. Within this context, the selection of people to source new knowledge from is grounded on the formal 'chain of command' and the division of roles amongst members of a given team.

Density values of both PT1 (0.32) and PT2 (0.46) indicated network structures potentially facilitating effective communication in that they were both below the 0.50 threshold that Krebs and Holley (no date) identify for the risk of communication and information overload. However, the *degree centrality* results for PT1 showed that the density values should not be taken at face value in terms of effectiveness of communication. Employees of the construction management company in PT1 had a clear advantage over the trade contractors in terms of the exchange opportunities that they accrued from the network structure (see **Table 3**). Such opportunities were probably much more evenly distributed for all members of PT2 almost regardless of their affiliations as evidenced by their *degree centrality* ranking which did not show affiliation-based clustering.

Table 3: Degree centrality results

Project 1			Project 2		
Degree centrality	**Company Role**	**Interviewee's Role**	**Degree centrality**	**Company Role**	**Interviewee's Role**
0.706	Construction Management	Project Manager	1.000	"Cradle to grave" project delivery	Project Manager
0.529		Commercial Manager	0.688	Client	Client representative 1
0.529		Project Director	0.563	"Cradle to grave" project delivery	Assistant Project Manager
0.529	Developer/ Client	Project Director	0.563	Architect	Partner/Principal Architect
0.471	Construction Management	Construction Manager	0.563	Client	Client representative 2
0.412		Commercial Assistant	0.500	M&E Engineering	Senior Engineer
0.412	Cost Consultant	Associate Cost Consultant	0.500	Client	Environmental H&S
0.412	Architect	Project Manager	0.500	"Cradle to grave" project delivery	Cost Manager
0.294	Cost Consultant	Project Surveyor	0.438	Client	Client representative 3
0.294	Construction Management	Document Controller	0.438		Project Sponsor
0.235	Concrete Works	Project Manager	0.438		Steering Group Member
0.235	M&E Cost Consultant	Associate M&E Surveyor	0.375		European Operations Capital PM
0.176	Logistics	Site Manager	0.375	"Cradle to grave" project delivery	Project Supervisor
0.176	Structural Steelwork	Site Manager	0.313	Building Services Maintenance	Engineer
0.118	Architect	Technical Co-ordinator	0.250	Client	Client representative 4
0.118	Façade Package Contractors	Project Manager	0.188	"Cradle to grave" project delivery	Team Leader
0.059	Structural Design (Qual. Cont.)	Senior Resident Engineer	0.063	H&S Consultants	Planning Supervisor & Safety Advisor
0.059	Building Management Systems	Project Manager			
0.32	Average		0.46	Average	

Table 4: Closeness centrality results

Project 1			Project 2		
Closeness Centrality	**Company Role**	**Interviewee's Position**	**Closeness Centrality**	**Company Role**	**Interviewee's Position**
0.773	Construction Management	Project Manager	1.000	"Cradle to grave" project delivery	Project Manager
0.654		Commercial Manager	0.762	Client	Client representative 1
0.654		Project Director	0.696	"Cradle to grave" project delivery	Assistant Project Manager
0.654	Developer/Client	Project Director	0.696	Architect	Partner/Principal Architect
0.630	Construction Management	Construction Manager	0.696	Client	Client representative 2
0.607		Commercial Assistant	0.667	M&E Engineering	Senior Engineer
0.586	Cost Consultants	Assoc.Cost Consultant	0.667	Client	Environmental H&S
0.586	Architect	Project Manager	0.667	"Cradle to grave" project delivery	Cost Manager
0.548	Concrete Works	Project Manager	0.640	Client	Client representative 3
0.531	Cost Consultants	Project Surveyor	0.640		Project Sponsor
0.531	Construction Management	Document Controller	0.640		Steering Group Member
0.500	Structural Steelwork	Site Manager	0.615		European Operations Capital PM
0.486	Logistics	Site Manager	0.615	"Cradle to grave" project delivery	Project Supervisor
0.472	Architect	Technical Co-ordinator	0.593	Building Services Maintenance	Engineer
0.447	M&E Cost Consultants	Associate M&E Surv.	0.571	Client	Client representative 4
0.425	Façade Package Contractors	Project Manager	0.552	"Cradle to grave" project delivery	Team Leader
0.395	Structural Design (Qual. Cont.)	Senior Resident Engineer	0.516	H&S Consultants	Planning Supervisor & Safety Advisor
0.354	Building Management Systems	Project Manager			
0.546	Average		0.661	Average	

A similar affiliation-based observation could also be made on the closeness centrality rankings, which could also be used as an indication of the of the social cohesion around a relationship as it "reflects how close an actor is to the other actors in the network" (Wasserman and Faust 1994). The closeness centrality ranking for PT1 demonstrated that the structure of PT1's network and its 'command chain' relegated members outside the management contracting firm at lower ranks, possibly reducing in turn their enthusiasm to put effort into coming up with new ideas (see **Table 4**). By contrast, PT2 network structure resulted in a much more diversified closeness centrality ranking that possibly fostered opportunities for truly intra-organizational cross-pollination of new ideas.

The *betweeness centrality* results corroborated the PMs' inevitable brokerage roles, as dictated by their 'command chains'. PM1 and PM2 respectively dedicated 29% and

36% of all their communication activity to controlling and filtering information/knowledge transfer between other nodes in their networks.

METHODOLOGICAL KNOW-HOW & LESSONS LEARNT

This section reports on the methodological know-how that the research team accumulated and considers the lessons learnt from applying SNA in the context of knowledge creation and absorptive capacity. This discussion falls into two categories: conceptual and operational.

At the conceptual level, it has been shown that SNA facilitates the exploration of the structural features of the social networks of the studied project teams. This was achieved through the basic interpretation of SNA metrics to determine how the project teams made use of their networks in sourcing knowledge and advice. This basic interpretation should be more advanced by correlating different metrics and interpreting the results of this correlation in order to get a more realistic understanding of how the networks behave.

A similar level of sophistication is also yet to be reached in the comparative analysis of the results of both SNA and content analysis. Once again establishing the correlations between these two different sets of results is the first step forward. As this has not yet been done, it may be possible that this research has just identified the actors who are key in terms of providing knowledge and information but not necessarily key in terms of creating new knowledge (Ashworth and Carley 2006). One way of testing this is to establish the correlation between a node’s position in the network as a knowledge and information provider and his/her knowledge creation capability.

At the operational level, basic utilization of SNA enabled the visualization of the teams’ networks, paving the way to very useful discussions amongst their members and between the research team and the project teams. It thus facilitated limited deployment of action research. This was regarded to be very beneficial by the industrial partners, who also showed a strong interest in having the tools and knowledge necessary to map the networks at different stages of their projects and to compare themselves with benchmarks for measuring knowledge creation capability and absorptive capacity of project teams. This wish raised the issues of the temporal nature of the social networks, the lengthy data collection process and the absence of such benchmarks.

Hence, the research team came to the conclusion that it was necessary to establish a much less time-consuming data collection tool without losing the opportunity to collect rich qualitative data and benchmarks for knowledge creation capability and absorptive capacity. This requires a longitudinal study on a statistically significant number of projects and thus poses an operational challenge. It may be possible to follow Ashworth and Carley’s (2006) approach and use simulation.

Another issue about data collection is the interpretation of knowledge by each interviewee. As we stated above, it is possible that some interviewees considered knowledge and information to be interchangeable. This condition results in the need to develop a strategy to understand whether each node’s interpretation of the knowledge interaction that was referred to in the name generator question(s) (see Table 1) was the same.

CONCLUSIONS

At the subject level, the main findings suggested that project team configurations have a high level of influence on the network structure, the selection of people to source new knowledge from is grounded on the formal ‘chain of command’ and the division of roles amongst members of a given team. It was also identified that there might be a correlation between the exchange opportunities that individuals accrue from the network structure and the roles of their affiliated companies in a project, e.g. construction management.

In the methodological context, this research has corroborated, among others, Lin (1990) and Scott (2000) by applying their principles in the knowledge creation and absorptive capacity context for the first time and thus showing that SNA is instrumental in assessing one of the ingredients of ‘social capital, i.e. accessibility to resources by individuals. It emerged from the discussions with industrial partners to the research project that this potential could be exploited by project teams in the industry, if structural benchmarks to assess knowledge creation capability that is inherent in a given network at a given point in time could be established and an easy-to-use management tool could be developed.

In this context, this research design had two main shortcomings in its deployment of SNA. First, the relational data was possibly biased as it was collected through name generation by recall. It is thus necessary to complement it with other methods such as observations so that the interview data can be triangulated, if this method is to be used in the future. Second, the network maps that were drawn were snap-shots at a point in time. Therefore, SNA has to be periodically repeated if its results are to be used for benchmarking. Given this, semi-structured interviews were not the most appropriate data collection strategies. It is critical that a more effective and less time-consuming data collection strategy is developed.

ACKNOWLEDGEMENTS

This paper is based on the findings of a research project that is funded by the Engineering and Physical Sciences Research Council (EPSRC, project reference: EP/C530160/1).

REFERENCES

Ashworth, M J and Carley, K M (2006) Who You Know vs. What You Know: the impact of social position and knowledge on team performance. *Journal of Mathematical Sociology*, **30**, 43–75.

Bourdieu, P (1986) The Forms of Capital. *In:* R G Richardson (Ed.) *Handbook of Theory and Research for the Sociology of Education*. New York: Greenwood.

Bresnen, M, Edelman L *et al*. (2003) Social practices and the management of knowledge in project environments. *International Journal of Project Management*, **21**(3), 157.

Burt, R S (1997) A note on social capital and network content. *Social Networks*, **19(**4), 355–73.

Burt, R S and Schott, T (1992) Relational Contents in Multiple Network Systems. In L C Freeman, D R White and A K Romney (Eds.) *Research Methods in Social Network* Analysis. New Brunswick and London: Transaction Publishers.

Ciborra, C U and Andreu, R (2001) Sharing Knowledge Across Boundaries. *Journal of Information Technology*, **16**, 73–81.

Cohen, W M and Levinthal, D A (1990) Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly*, **35**, 128–52.

Fong, P S W (2003) Knowledge creation in multidisciplinary project teams: an empirical study of the processes and their dynamic interrelationships. *International Journal of Project Management*, **21**(3), 479–86.

Freeman, L C (1979) Centrality in Social Concepts. *Social Networks*, **1**, 215–39.

Freeman, L C (1992) Social Networks and the Structure Experiment. In L C Freeman, D R White and A K Romney (Eds.) *Research Methods in Social Network* Analysis. New Brunswick and London: Transaction Publishers.

Friedkin, N E (1983) Horizons of Observability and Limits of Informal Control in Organisations. *Social Forces*, **62**(1), 54–77.

Ghoshal, S and Moran, P (1996) Bad for Practice: a critique of the transaction cost theory. *Academy of Management Review*, **21**, 13–47.

Grant, R M (1991) The Resource-based Theory of the Competitive Advantage: implications for strategy formulation. *California Management Review*, **34**(spring), 114–35.

Groshal, S and Moran, P (1996) Bad for Practice: A Critique of the Transaction Cost Theory. *Academy of Management Review*, **21**(1), 13–47.

Ibarra, H (1993) Network Centrality, Power, and Innovation Involvement: Determinants of Technical and Administrative Roles. *The Academy of Management Journal*, **36**(3), 471–501.

Kess, P and Haapasalo, H (2002) Knowledge Creation through a project review process in software production. *International Journal of Production Economics*, **80**, 49–55.

Krebs, V and Holley, J (no date) *Building Smart Communities through Network Weaving*. DOI.

Kurul, E, Colantonio A *et al*. (2007) Knowledge Creation and Absorptive Capacity: influences of social capital. *In: CIB World Congress*, Cape Town, South Africa.

Kurul, E, Colantonio A *et al*. (2006) Influences of Social Capital on Knowledge Creation. In: *World Conference on Accelerating Excellence in the Built Environment*, Birmingham, UK.

Lang, J C (2001) Managerial Concerns in Knowledge Management. *Journal of Knowledge Management*, 5(1), 43–57.

Lank, E (1997) Building Structural Capital: a new key to generating business value. *Knowledge and Process Management*, **4**(2), 73–9.

Lin, N (1999) Building a Network Theory of Social Capital. *Connections*, **22(**1), 28–51.

Loosemore, M (1998) Social network analysis: using a quantitative tool within an interpretative context to explore the management of construction crises. *Engineering, Construction and Architectural Management*, **5**(4), 315–26.

Marsden, P V (1990) Network Data and Measurement. *American Sociological Review*, **16**, 435–63.

Mizruchi, M S and Potts, B B (1998) Centrality and power revisited: actor success in group decision making. *Social Networks*, **20**, 353–87.

Nahapiet, J and Ghoshal, S (1998) Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, **23**, 242.

Nohria, N and Eccles, R G (Eds.) (1992) *Networks and Organisations*. Boston, MA: Harvard Business School Press.

Otte, E and Rousseau, R (2002) Social network analysis: a powerful strategy, also for the information sciences. *Journal of Information Science*, **28**(6), 441–53.

Pryke, S D (2004) Analysing construction project coalitions: exploring the application of social network analysis. *Construction Management and Economics*, **22(**9), 787–97.

Pryke, S and Pearson, S (2006) Project Governance: case studies on financial incentives. *Building Research and Information*, **34(**6), 534–45.

Quintas, P, Hutchinson V *et al*. (2003) *A Systematic Analysis of Knowledge Practices in Other Sectors: lessons for construction*. London: Department of Trade and Industry.

Reagans, R and McEvily, B (2003) Network Structure and Knowledge Transfer: The Effects of Cohesion and Range. *Administrative Science Quarterly*, **48**, 240–67.

Roth, J (2003) Enabling knowledge creation: learning from an R&D organization. *Journal of Knowledge Management*, **7(**1), 32–48.

Scott, J (2000) *Social Network Analysis: a handbook* (London, Thousand Oaks, New Delhi: Sage Publications).

Sharkie, R (2003) Knowledge Creation and Its Place in the Development of Sustainable Competitive Advantage. *Journal of Knowledge Management*, **7**(1), 20–31.

Sparrowe, R T, Liden R C *et al*. (2001) Social Networks and the Performance of Individuals and Groups. *The Academy of Management Journal*, **44**(2), 316–25.

Wasserman, S and Faust, K (1994) *Social Network Analysis: methods and applications* (Cambridge: Cambridge University Press).

Winch, G (2002) *Managing Construction Projects* (Oxford: Blackwell Science).

Yin, R (1994) *Case study research: Design and methods*. 2ed. Thousand Oaks, CA: Sage Publishing.

STAKEHOLDER VALUE DRIVERS OF PUBLIC PRIVATE PARTNERSHIPS IN GREECE

Athena Roumboutsos[1]

Shipping, Trade and Transport, University of the Aegean, 2A Korai str, Chios 82100, Greece

Public Private Partnerships are described as endeavours that seek to achieve value and benefit for both the public and private sector. As the procurement process matures, value drivers crystallize, providing the basic negotiation framework. In countries, such as Greece, where experience is limited, this knowledge is not registered, though, imperative to achieving progress in the sector. The value drivers of PPP projects as perceived by the prime stakeholders of a PPP project, i.e. construction companies, the public authorities and the financial lenders, in Greece are presented herewith. These are derived through a questionnaire survey. The results indicate the varying perceptions between stakeholder groups and are compared to similar studies undertaken and provide insight as to barriers to minimize the pre-contract period of PPP engagements.

Keywords: Public–Private Partnerships, stakeholders, value for money.

INTRODUCTION

A key motive for public authorities' interest in Public Private Partnerships (PPPs), as stated in the green paper, is that PPPs enable governments, constrained by the EU's own fiscal rules, to make more investments in public services. In addition to the need to launch investment programmes, which would not have been possible within the available public-sector budget, within reasonable time (European Investment Bank, 2005), the scheme has been made even more favourable due a recent ruling by Eurostat (the Statistical Office of the EC) in February 2004, according to which the assets involved in a PPP should be classified as non-government assets, and therefore recorded off balance sheet for government, if the private partner bears the construction risk, as well as, either availability or demand risk.

Nonetheless, governments need to demonstrate value for money (VFM). Central to this demonstration is the "comparison" of benefits and costs between the two procurement options (i.e. traditional and PPP), where the allocation of risks and risk premiums combined with discount rates affect the final outcome. Grimsey and Lewis (2005), in a comparison study of methods used in 29 countries, found that the Public Sector Comparator (PSC) was only applied in 6 countries, namely the UK, Australia, The Netherlands, South Africa, Canada and Japan, while the rest used alternative methods.

However, PPPs, if they are to provide value, should not only be about financing of capital investments, but about exploring the full range of private sector management, commercial and creative activities, while securing value for money (VFM) for all

[1] athena@aegean.gr

stakeholders involved. The VFM assessment is not an exact science, the net result being that opinions on and perceptions of VFM vary from stakeholder to stakeholder (Akintoye *et al*. 2003). Problems reported in PPPs, such as high tendering costs, complex negotiations, costs restrains on innovation etc, stem from this very issue of varying stakeholder value drivers (Spackman 2002; Tiong *et al.* 1992).

The issues surrounding VFM are threefold: the identification of value for money drivers; the estimation of their importance and relation to success factors; and, finally, the investigation of the varying importance among stakeholder groups.

To the end, the first issue has been extensively covered by many researchers, academia and practitioners (Akintoye *et al*. 2003; Ball *et al*. 2003; Edwards and Shaoul 2002; Grimsey and Lewis 2005; Leiringer 2006; Nisar 2007; Pitt *et al*. 2006 etc.. Many of these are similar to the “VFM drivers” identified in the report “Value for money drivers in the private finance initiative” (Arthur Andersen and Enterprise LSE 2000). Li *et al*. (2004), addressing the second issue, after extensively reviewing the literature on value for money drivers looked into their relative importance to critical success factors for PPP/PFI construction projects in the UK. Finally, the fact that perceived VFM varies between stakeholders, i.e. the third issue, has, to date, received little attention by researchers.

To this end, research presented herewith investigates the perceptions on value of PPPs by the prime stakeholders, through a questionnaire survey in Greece. Findings are compared to similar studies undertaken in the UK.

BACKGROUND

A review of informed literature on PPPs would indicate that a variety of the characteristics of the PPP are promoted as key to the creation of VFM and, consequently, lead to the success of the endeavour, thus, constituting key success factors. The aspects of the PPP procurement process most frequently mentioned from attributed sources are listed below.

Table 1: Summary of critical success factors for PPPs (source: Li *et al*. 2005)

Critical success factor	**Source**
Strong private consortium	Jefferies *et al.* (2002), Tiong (1996), Birnie (1999);
Appropriate risk allocation and risk sharing	Qiao *et al.* (2001), Grant (1996)
Competitive procurement process	Jefferies *et al.* (2002), Kopp (1997), Gentry and Fernandez (1997)
Commitment/responsibility of public/private sectors	Stonehouse *et al.* (1996), Kanter (1999), NAO (2001b)
Thorough and realistic cost/benefit assessment	Qiao *et al.* (2001), Brodie (1995), Hambros (1999)
Project technical feasibility	Qiao *et al.* (2001), Tiong (1996), Zantke and Mangels (1999)
Transparency in the procurement process	Jefferies *et al.* (2002), Kopp (1997), Gentry and Fernandez (1997)
Good governance	Qiao *et al.* (2001), Frilet (1997), Badshah (1998)
Favourable legal framework	Bennett (1998), Boyfield (1992), Stein (1995), Jones *et al.* (1996)
Available financial market	Qiao *et al.* (2001), Jefferies *et al.* (2002), McCarthy and Tiong (1991), Akintoye *et al.* (2001b)
Political support	Qiao *et al.* (2001), Zhang *et al.* (1998)
Multi-benefit objectives	Grant (1996)
Government involvement by providing guarantees	Stonehouse *et al.* (1996), Kanter (1999), Qiao *et al.* (2001), Zhang *et al.* (1998)
Sound economic policy	EIB (2000)
Stable macro-economic environment	Qiao *et al.* (2001), Dailami and Klein (1997)

Well-organized public agency	Boyfield (1992), Stein (1995), Jones *et al.* (1996) Finnerty (1996)
Shared authority between public and private sectors	Stonehouse *et al.* (1996), Kanter (1999)
Social support	Frilet, 1997
Technology transfer	Qiao *et al.* (2001)

The Arthur Andersen and Enterprise LSE report (2000) identified 18 value-for-money drivers for the UK and distinguished them as primary and secondary depending on the average score they obtain through interviews with PPP/PFI participants. Li *et al*. (2005) through an extensive literature review identified 19 critical success factors (Table 1), 18 of which were ranked in through their research.

In Table 2, this ranking is compared to that of the Arthur Andersen and Enterprise LSE report (2000). It is evident that success factors and VFM drivers "coincide" in many cases, while differing in importance. This may be due to the evolution of perceptions realized between the two studies as the market matured through the undertaking of more projects.

Table 2: Comparison of literature ranking

Li *et al*. (2005) Critical Success Factors	**Rank**	**Anderson and Enterprise LSE (2000) VFM Drivers**	**Rank**
Appropriate risk allocation and risk sharing	2	Risk transfer	1
Transparency in the procurement process	10	Transparency of process	12
Competitive procurement process	12	Competition	5
Commitment/responsibility of public/private sectors	4	Long term nature of contracts	3
Thorough and realistic cost/benefit assessment	5	Public sector comparator	10
Well-organized public agency	7	Public sector project development skills	9
Good governance	8	Private sector management skills	6
Shared authority between public and private sectors	17	Alignment of interest of authority and contractor	8
Multi-benefit objectives	14	Project bundling	17
		Innovation	7
Project technical feasibility	6	Output based specifications	2
Strong private consortium	1		
Available financial market	3		
		Cost of capital	13
		Deal flow	14
Favourable legal framework	9		
		Performance measurement and incentives	4
		Involvement of third party financiers	18
Political support	11		
Government involvement by providing guarantees	16		
Sound economic policy	13		
Stable macro-economic environment	15		
Social support	18		
		Public Sector implementation	15
		Release of hidden asset value	16
		Quality of advice to public sector and bidders	11

The research undertaken in Greece focused on the "common" factors identified in Table 2, as well as factors identified as important in the local market. The principal aim was to identify the relative importance of these factors for the Greek market. In addition, it was equally important to identify a possible maturing process. More specifically, the factors presented herewith are:

1. Risk allocation – optimal allocation and valuation of risk.
2. Competition.
3. Contract duration and scope.
4. Innovation.
5. Borrowing costs – financing of the project.
6. Private sector versus Public sector management skills.
7. Performance measurement and incentive.

The above do not respond to all factors investigated but only to those on which each category of stakeholders had more consolidated views.

RESEARCH SURVEY DESCRIPTION

The current survey is part of a questionnaire survey conducted to register risk allocation preferences, partnering and value-for-money drivers of private and public entities interested in Greek PPP projects. In particular, the stakeholders addressed were: construction companies, financiers (banks), ministries interested in promoting PPP infrastructure within their scope of activities and associations with a stake in PPP procurement. Table 3 presents the numerical figures of the survey. The description of the participants follows herewith.

Table 3: Survey respondents

	Construction Companies	Banks	Ministries	Associations	Total
Respondents N	19	5	5	2	31
% Total	61.3	16.1	16.1	6.5	100
Universe	42	5	5	8	60
Response rate	45%	100%	100%	25%	52%

Construction companies

Construction companies selected for the survey were companies eligible to undertake PPP projects, i.e. those classified as classes 6 and 7 by the Greek Ministry of Public Works, thus, those companies having the respective construction experience and financial background. It should be noted that, in Greece, there are seven classes and a newly established construction company with no experience enters the register at class 1 and is “allowed” to undertake low budget, and consequently (in most cases) low technical difficulty works. Questionnaires were addressed directly to the company heads and followed by interviews for additional information and clarification. The objective was to register “company” rather than individual opinions.

The survey was conducted in the winter of 2004–2005, in a very turbulent business environment of recession for the construction industry following the Athens 2004 Olympic Games. Of the 61 companies classified under the 6^{th} and 7^{th} construction class in the 2004 Ministry register, only 42 (universe population) were found to remain in operation. This was due to a number of mergers that took place immediately after, or just before the completion of works between consortium members. 19 construction companies responded to the questionnaire, i.e. a response rate of 45%. The respondents are presented in Table 4. The respondent companies were all highly reputable in Greece (two are included in the top 100 European Companies listing) and active in most infrastructure sectors. The stated field of expertise included buildings, ports, transportation, power and energy, water and sanitary.

As depicted, the majority of the respondent companies have been established before 1990. A total of 41% have an annual turnover of more than 40 million Euro, while 72% of the companies interviewed claim that more than 60% of their turnover is generated through public contracts. Thirteen companies have more than 100 employees; 68% of the companies surveyed had participated in a PPP procurement procedure. Half of these companies (54% in total) were involved in a completed PPP project. All, but one, companies expressed interest in participating in a PPP project.

Table 4: Respondent construction companies' profile

Property	Description	Frequency	%
Year of establishment	Before 1970	5	31
	1970–1990	7	35
	1990–2002	7	35
Number of employees	<100	6	31
	101–500	9	47
	>500	4	21
Average annual turnover in MEuro	6–40	11	58
	41–100	3	16
	101–250	2	10
	>250	3	16
% of turnover originated from public sector	0–40%	3	16
	41–60%	2	10
	61–80%	7	37
	81–100%	7	37

Financing institutions
Not all Greek based banks were interested in PPPs and, thus, were not included in the survey. The ones interested were "The National Bank of Greece", "The Commercial Bank", "Alpha Bank" and "Eurobank". The European Investment Bank (EIB), due to the bank's great involvement in PPP projects, was also included in the survey focusing on the Greek market. Thus, concerning the financing institutions, the survey covered all potential players and while the number of respondents is small (five), it constitutes a response rate of 100%.

Public sector
The identification of key persons in position to respond to the questionnaire in the Greek public sector was a task of considerable difficulty. One major problem stemmed from the fact that the government was preparing the Greek legislation concerning PPP projects and most government officials and key advisors to ministers were reluctant to express opinions which might not have been in line with the final outcome. Major ministries were targeted intensely, i.e. the Ministry of Finance and Economics and specifically members of the PPP taskforce, the Ministry of Public Health, the Ministry of Education, the Ministry of Internal Affairs, the Ministry of Public Works.

Associations
A number of associations and NGOs influenced by the PPP procurement method were targeted. However, only two were in a position to report their positions as authorities while the rest only personal positions and, thus, were excluded from the sample. The

two that responded were the Technical Chamber of Greece and the Association of Designers and Planners.

PRESENTATION OF SURVEY RESULTS AND DISCUSSION

The importance of value drivers identified in the literature was explored by means of a Likert scale rating questions, i.e. statements for which participants were requested to state their level of agreement on a 1 to 5 scale (Table 5). A number of these question-statements were followed by multiple-choice questions aiming to verify the reason of agreement stated (Tables 6, 7 and 8). For example, long-term contracts may be equally important for all participants but for different underlining reasons.

Likert scale rating questions were structured in both positive and negative patterns in order to verify the unbiased of the responses and the administered questionnaires had questions ordered differently, in random, so as to avoid distortion of responses due to fatigue.

Table 5: Cross tabulation of mean scores (1 = extremely important to 5 = not important)

		Construction Companies		Banks		Ministries		Associations		Total	
		Mean	**Sd***	**Mean**	**Sd***	**Mean**	**Sd***	**Mean**	**Sd***	**Mean**	**Sd***
1	Transparency in procurement process	1.39	0.78	1.00	0.00	1.50	0.58	1.00	0.0	1.32	0.67
2	Private sector's competent response to innovation and legislation change	1.44	0.51	1.75	0.50	2.00	0.82	1.50	0.71	1.57	0.57
3	Alignment of Public and Private interests	1.72	0.75	1.50	0.58	2.00	1.41	1.50	0.71	1.71	0.81
4	Additional entrepreneurial activities during the asset life cycle.	1.94	1.11	4.25	0.50	2.00	1.00	3.00	2.83	2.37	1.39
5	Cost/benefit assessment	2.00	0.97	2.75	0.96	2.67	2.08	1.00	0.0	2.11	1.12
6	Combined procurement of contractor and financier	2.06	0.64	1.50	0.58	1.25	0.50	1.50	0.71	1.82	0.67
7	Risk allocation	2.11	0.96	1.50	0.58	2.50	1.00	1.00	0.0	2.00	0.94
8	More PPP tenders	2.28	1.18	2.25	0.96	2.00	1.00	1.00	0.0	2.15	1.10
9	Favourable legal framework	2.29	1.11	3.00	0.82	3.00	1.41	2.50	2.12	2.52	1.16
10	Public sector's level of experience in PPPs **	3.94	0.73	3.25	0.96	4.25	0.50	3.50	0.71	3.86	0.76
11	Project Mng *not* core business for the public sector Authority**	2.06	1.21	2.25	1.89	3.00	1.63	1.50	0.71	2.18	1.33

Note: *Sd = standard deviation, ** Likert scale rating: 1 = extremely high to 5 = inadequate

Survey responses were analysed using the SPSS statistical package. Only descriptive analysis was carried out due to the limited number of responses, regardless of the significant response rate. Table 5 presents the results by stakeholder category and in total. It is noted that totals are presented for reasons of completeness rather than significance. The calculated standard deviation (noted as sd in the table) denotes the value of the mean response for each item on the table.

Risk allocation – optimal allocation and valuation of risk

From a financial perspective, it is reasonable to suggest that the required rate of return on an investment increases as the amount of risk in the investment increases (Brigham 1985). Thus, the theory and practice that in PPPs risk should be borne on the basis of the principle that the party best able to control or manage a risk should take responsibility for the risk in order to achieve the optimum (lowest) cost is sound (Loosemore 2007). The allocation of risk is seen by many as the most crucial element in a PPP being able to achieve VFM. Nonetheless, Lam (1999), in his sectoral review of risks associated with major infrastructure projects implemented all over the world, concluded that optimum risk allocation is not easy to obtain as much depends on the relative bargaining power of the parties and the potentiality of the reward for taking the risks.

Risk allocation (item No. 5 in Table 5) was expected to figure as “extremely important” (mean = 1) for all stakeholder groups. However, this was not identified in the survey. As noted in Table 5, mean values were 2.11 and 2.50 for construction companies and the public sector, respectively and only the banks and the associations (mean 1.50 and 1.00, respectively) gave risk allocation the expected relative importance.

This response may be due to the fact that while less than optimum allocation of risks has been identified in the first PPP projects in Greece (Roumboutsos and Striagka 2004), their perceived end value was not reduced.

Finally, findings are comparable to those reported by Li *et al*. (2005). An interesting point is the fact that in both cases the public sector placed less importance on risk allocation than the private.

Competition

A PPP project, like a conventional project, has to go through the tendering process. Where a PPP has been won in open tender, it makes the argument for VFM easier to substantiate. The element of competition has additional benefits to the public client during negotiations. However, this needs to be balanced against the bidding costs as these will more than likely be recovered elsewhere.

Transparency in the tendering procedures (item No. 1 in Table 5) and a *favourable legal framework* are elements (item No. 9 in Table 5) that reinforce competition. As depicted in Table 5, *transparency in the tendering procedures* was identified as the most important item across all stakeholder groups, while the *legal framework* was estimated as marginally important though under discussion during the survey. This may be due to the fact that experience with PPPs to the date of the survey was not connected to specific legislation and that the majority of stakeholders view a legal framework as *safety in the bidding procedure* (see Table 6).

In addition to the above, as shown in Table 6, the majority of stakeholders (60%, 75% and 100% of the banks, public clients and associations) consider price-lead competition a benefit for the public sector, while construction companies (56%) express scepticism concerning the possibility of poor deals that will ultimately affect the public sector.

A minority of respondents registered their fear of the creation of oligopoly market conditions, which in effect has been identified in recent PPP contracts. This is really the antithesis of competition. The barriers to entry of new competitors to PPP procurement are high. The absence of competition from the procurement process can only result in a loss of credibility, and potentially VFM, for PPP procurement. Bid costs can therefore be seen as having a negative and real impact upon PPP and VFM, particularly so when the number of bidders is reduced to one.

The importance of *more PPP tenders* in order to balance the costs, figured with a relative significance (see Table 5, item No. 8).

Table 6: Views related to competition issues

	Construction Companies	Banks	Ministries	Associations	Total
Price – lead competition					
Benefit to public sector	33%	60%	75%	100%	46%
Poor deals for private sector and impact on public sector	56%	0%	25%	0%	39%
Oligopoly market conditions	6%	20%	0%	0%	7%
Other	6%	20%	0%	0%	7%
Legal framework					
Safety to the bidding procedure	94%	100%	75%	100%	93%
Other	6%	0%	25%	0%	7%

Contract duration and scope

The duration of the contract and the scope of the contract works are very closely linked. The long duration of PPP contracts and the inclusion of the facilities management function allow the consortium to consider properly whole life costing issues in order to minimize the contract period costs. Additionally, value cannot be achieved unless, during initial procurement, bidders grasp the opportunity to integrate design, construction and facilities management issues to minimize life cycle costs and optimize operational efficiency (Spackman 2002; HM Treasury 2003). Furthermore, the manner in which PPPs are usually structured requires the consortium to construct the asset(s) before it can receive payments. This very often results in the consortium investing more in the initial stages of the contract than would be done under standard procurement arrangements to hasten the completion of the building relative to "traditional" construction.

This view was challenged by Leiringer (2006) – as though a logical conclusion, it has not been empirically verified. The survey findings (Table 7) support this view. Life cycle planning is not the primary objective of the private sector supplier, who, in the majority, views long-term contracts as a means to secure ROE.

Indisputably, from the contractor's point of view, there is benefit in life cycle planning *in the event the contract is won*. Otherwise, it is an additional loss. Consequently, contractors will view long-term contracts as a means to secure ROE, as operational costs (since no or minimum life cycle planning was involved) would most likely reduce profits from revenues. This perception is in total contrast with the interests of banks and public sector, since these parties would be interested in an overall reduction in project risks that is connected to the minimization of operational costs and the overall quality of the project, which would, possibly in addition, secure revenues.

Finally, the view presented by the contractors is in line with their view concerning price-lead competition (i.e. poor deals for the private sector with ultimate impact on the public).

Table 7: Views on contract duration

	Construction Companies	Banks	Ministries	Associations	Total
Long-term contracts					
Required for high investment projects	44%	20%	25%	100%	41%
Invoke life cycle planning	28%	80%	50%	0%	38%
Alternative approaches to investment and service delivery	28%	00%	25%	0%	21%
Length of contract depends					
Expected project life cycle	0%	20%	25%	0%	7%
ROE	94%	40%	25%	100%	76%
Public sector requirements	0%	0%	50%	0%	7%
Other	0%	40%	0%	0%	7%

Innovation

The ability to innovate is directly related to the quality of the output specification and the element of competition during the initial stages. This has been exemplified in successive rounds of PPP prison procurement that showed that a combination of innovation and competition led to reductions in costs at each stage (HM Treasury 2003). The *aspect of innovation* figured as the second most important factor in the survey (see Table 5, item 2) across all stakeholder groups with a strong convergence depicted by the small standard deviation (sd) figures, ranging from 0.50 to 0.82.

Borrowing costs – financing of the project

The fact that the government can borrow more cheaply than the private sector is an accepted fact. It is assumed by many that the differential in the cost of capital between the public and private sectors means that the consortium's higher cost of capital will have a negative impact on the VFM case, but, it is argued, determining VFM is not simply about comparing interest rates. This is not correct when the cost of the project is the same regardless of the procurement route (Grout 1997). Thus, if the cost of capital is to be considered, it should be on the difference between the cost of purchasing the asset traditionally and through PPP. Therefore, the cost of capital has a smaller role to play in the VFM argument than many may first appreciate.

The importance of establishing a *thorough cost/benefit assessment*, as indicated in the survey, is more important for the construction companies and the associations than it is for the banks and the public sector (see Table 5, item 5). On the other hand, *combined procurement of financier and constructor* seem important for all stakeholders except construction companies (see Table 5, item 6).

Table 8: Impact on public funding

	Construction Companies	Banks	Ministries	Associations	Total
Availability of public funds	50%	0%	50%	100%	45%
Flexibility of Public funds	39%	60%	25%	0%	38%
Commitment of public funds	11%	20%	25%	0%	14%
Other	0%	20%	0%	0%	3%

Finally, there is always the assumption made that the government would be able to raise the capital if the project were not to proceed as a PPP. Table 8 illustrates the stakeholder perceptions on *the effect PPPs have on public funds*. It is evident that there is no converging view both within and among stakeholder groups.

Private sector vs. public sector management skills
For a variety of reasons that no one appears to be able to put their finger on, management skills are viewed as essential. Whether or not there is a real difference between management skills of the private sector and the public sector is open to debate. However, there is a real difference between the systems and procedures required within the public sector when compared to the private. It could be argued that the levels of accountability, less in the private sector, and delegation of authority, more in the private sector, allow "things to happen faster" and, thus, the perceived value of "private sector management skills".

In any case, PPPs are a complex task and one that places a very high demand on the capability of the public sector. Additionally, it would also appear to be common sense that the overall project success is to a very large determined by the ability of the public sector client to adopt and sustain the best value regimes through out the project life (Akintoye *et al.* 2003).

This aspect has been registered in the survey in concerning the *public sector level of experience in PPPs*, which was rated very low by all participants, and the essentiality of *project management carried out by the public sector*, which was equally considered outside the core responsibilities of the public sector (see Table 5, items 10 and 11 respectively).

However, PPPs are viewed by all stakeholders as an *alignment of private and public interests* in such as way as to establish better overall management (see Table 5, item 3).

Consequently, the assumption concerning private and public sector management skills holds true for the Greek PPP stakeholders.

Performance measurement and incentives
Performance measurements and incentives of themselves do not materially affect the empirical argument for or against VFM. However, they will increase the confidence of the client if they are set and apportioned correctly. Recent commentary has stated that the simplistic assumption that there is a necessary and direct relationship between project incentives and performance outcomes is doubtful (Bresnen and Marshall 2000).

Survey findings (Table 5, item 4) indicated that the possibility of *additional entrepreneurial activities during the asset life cycle* was viewed as positive by the construction companies and the ministries (mean = 1.94 and 2.00, respectively), while the other stakeholders were very negative (mean 4.25, and 3.00 for banks and associations).

Comparison with other findings
Table 9 below compares the ranking of some of the value drivers for PPPs as identified in the literature and the present research.

It is evident that ranking changes over time and between countries as the importance of value drivers as depicted by the stakeholders seem to be dependent on the particular market environment.

Transparency in the process seems to be of prime interest in Greece, while of lesser importance in the UK, where risk allocation is of essence.

Table 9: Comparison of findings

Li *et al*. (2005) Critical Success Factors	**Rank**	**Anderson and Enterprise LSE (2000) VFM Drivers**	**Rank**	**Present Findings**	**Rank**
Appropriate risk allocation and risk sharing	2	Risk Transfer	1	Risk Transfer	5
Transparency in the procurement process	10	Transparency of process	12	Transparency of process	1
Thorough and realistic cost/benefit assessment	5	Public sector comparator	10	Cost/benefit Assessment	6
Shared authority between public and private sectors	17	Alignment of interest of authority and contractor	8	Alignment of interest of authority and contractor	3
Multi-benefit objectives	14	Project bundling	17	Additional entrepreneurial activities	8
		Innovation	7	Innovation	2
Favourable legal framework	9			Favourable legal framework	9

CONCLUSIONS

A questionnaire survey was undertaken in the Greek PPP market among stakeholder groups in order to identify key value drivers. These were found to be country specific when compared to respective findings carried out in the UK. On a number of factors, stakeholder groups varied significantly as to the importance attributed. Three of which –risk allocation, competition and contract length – are considered to have an impact on the pre-contract bidding and negotiation process, as parties have contrasting views as to the targeted benefit and many potential bidders are discouraged.

A maturing process was not identified, as perceptions are considered to be due, principally, to the prevailing market environment and the local experience.

Additionally, it was found that the gross distinction between private and public stakeholders is not substantiated as financing institutes differ considerably to the private sector clients (construction companies).

Further research should be undertaken as to the varying perceptions on value drivers of PPP stakeholders.

REFERENCES

Akintoye, A, Hardcastle, C, Beck, M, Chinyio, E and Asenova, D (2003) Achieving best value in private finance initiative project procurement. *Construction Management and Economics*, **21**, 461–70.

Arthur Anderson and Enterprise LSE (2000) *Value for Money Drivers in the Private Finance Initiative*. London: The Treasury Taskforce.

Ball, R, Heafey, M and King D (2003) Risk transfer and value for money in PFI projects. *Public Management Review*, **5**(2), 279–90.

Bresnen, M and Marshall, N (2000) Motivation, commitment and the use of incentives in partnerships and alliances, *Construction Management and Economics*, **18**(5), 587–98.

Brigham, M and Marshall, N (1985) *Financial management theory and practice.* 4ed. New York: The Dryden Press.

Edwards, P and Shaoul, J (2003) Partnerships: for better, for worse? *Accounting, Auditing and Accountability Journal*, **16**(3), 397–421.

EIB (2005) *Evaluation of PPP Projects Financed by the EIB*. EIB Publications.

Green Paper on Public-Private Partnerships and Community Law on Public Contracts and Concessions. COM (2004) 327 final. Brussels 30.04.2004. Available online: http://europa.eu.int/comm/internal_market/publicprocurement/docs/ppp/greenpaper/com-2004-327_en.pdf

Grimsey, D and Lewis, M K (2005) Are Public Private Partnerships value for money? Evaluating alternative approaches and comparing academic and practitioner views. *Accounting Forum*, **29,** 345–78.

HM Treasury (2003) *PFI: meeting the investment challenge*. London: The Stationery Office.

Lam, P T I (1999) A sectoral review of risks associated with major infrastructure projects. *International Journal of Project Management*, **17**(2), 77–87.

Leiringer, R (2006) Technological innovation in PPPs: incentives, opportunities and actions. *Construction Management and Economics*, **24**(3), 301–8.

Li, B, Akintoye, A, Edwards, P J and Hardcastle, C (2005) Critical success factors for PPP/PFI projects in the UK construction industry. *Construction Management and Economics*, **23**(5), 459–71.

Loosemore, M (2007) Risk allocation in the private provision of public infrastructure. *International Journal of Project Management,* **25**, 66–76.

New decision of Eurostat on deficit and debt Treatment of public-private partnerships 11/02/2004. Available online: http://europa.eu.int/rapid/pressReleasesAction.do?reference=STAT/04/18&format=HTML&aged=0&language=EN&guiLanguage=en

Nisar, T M (2007) Value for money drivers in public private partnership schemes. *International Journal of Public Sector Management,* **20**(2), 147–56.

Pitt, M, Colins, N and Walls, A (2006) The private finance initiative and value for money. *Journal of Property Investment and Finance*, **24**(4), 363–73.

Roumboutsos, A and Striagka, F (2004) Value for money drivers in Public Private Partnerships in Greece. *In: 3rd Scientific Conference on Project Management, Clustering in Construction Project Management*, 24–5 September, Thessaloniki, Greece.

Spackman, M. (2002) Public-private partnerships: lessons from the British approach. *Economic Systems*, **26**, 281–301.

Tiong, L K R, Yeo, K I and McCarthy, S C (1992) Critical success factors in winning BOT contracts. *Journal of Construction Engineering and Management ASCE*, **118**(2), 217–28.

DIFFERENCES IN IMPLEMENTATION AND EFFECTS OF THE PUBLIC PROCUREMENT ACT IN THE EU CONSTRUCTION SECTOR.

Stefan Olander and Kristian Widén[1]

Construction Management, Lund University, PO Box SE 221 00, Lund, Sweden

All member countries in the EU must follow the given directive for public procurement that has been decided upon. The purpose of the directive is to ensure sufficient public procurement and sound use of public resources. However, knowledge about the implementation and effects of the directive is limited. One clear indication is that the effects vary between different countries in the EU. A preliminary study of the implementation of the public procurement act in Sweden and Denmark for the construction sector has been conducted, with the aim of obtaining knowledge of how and why implementation and effects vary. One distinction is that the number of appeals concerning public procurement is higher in Sweden than in Denmark that might depend on a different implementation of the directive, mainly because Sweden has added amendments to the directive while Denmark has not. The variation of implementing the directive between member countries may have a negative impact on the opportunities of obtaining the best possible service and technical solution in the public procurement process.

Keywords: construction sector, European law, public sector, procurement.

INTRODUCTION

The public sector is a highly influential participant in the construction industry, as it exercises a major role in several ways. It is, for example, policy-maker, legislator and client (Andersson 2003) and, in some cases, performs services directly (Andersson 2004). The public sector, as client, can influence and motivate other actors to a significant extent (Edquist *et al*. 2000). Public policies, laws and programmes are other ways in which governments can influence innovation in the industry (Manseau and Seaden 2001).

The European public procurement directive has both positive and negative effects (e.g. NOU 1998; Ramsey 2006). Positive effects are that public procurement across Europe has the same basic prerequisites and, thus, can generate a clearer competition among suppliers. A negative effect is cost driving and time-consuming bureaucratic routines. Other issues that have been highlighted, especially by parties in the construction sector, are difficulties of adopting new forms of cooperation, innovative solutions and implementation of environmental targets in the procurement process. The new directive (Dir 2004/18/EC) is stricter, but also opens up for more collaborative forms of cooperation, such as partnering and PFIs, through, for example, the use of competitive dialogue (Finansdepartementet 2006; Ramsey 2006). In particular, the 'competitive dialogue' procedure would allow early dialogue with

[1] stefan.olander@bekon.lth.se

industry and provide information on what the public sector wants to buy. This would guide and stimulate the creation of new ways of working and ideas (Manchester Business School 2006).

The purpose of the research presented here is to obtain a preliminary view of how a difference in the implementation of EU public procurement directives will affect the construction industry. Two countries, Denmark and Sweden, act as examples of this phenomenon. The research should be seen as a baseline for further studies about how the public procurement process acts as an enabler or barrier for change and development for the construction sector and if national legislations have an effect on this.

The research presented here should be seen as a preliminary study of public procurement within the European Union. Sweden has taken the approach of adding amendments to the EU directive whilst other member countries, e.g. Denmark, have adopted the EU directive as is. The data gathered consists mainly of official documents and public investigations concerning the implementation and effects of the public procurement act within the European Union in general and Sweden in particular. In addition, the views of construction sector clients have been obtained through an informed dialogue with a representative of the Swedish construction client organisation; additionally, a representative from the Danish construction client organisation has been contacted in a similar way to obtain information of relevant differences between Sweden and Denmark in the implementation of the public procurement act.

PUBLIC PROCUREMENT

All member states in the EC have to follow the EU regulation on public procurement. The purpose of the regulation is to enhance competitiveness and to eliminate non-tariff barriers to intra-community trade (Bovis 2006), and to promote transparency and prevent corruption (Sanderson 1998). The rationale behind the open market is that for many sectors, for example the financial sector, business across the globe was already harmonising procedures and specifications – and as a sharp-edged tool, not because of bureaucratic obsession for its own sake (MacGillycuddy 1988). Public authorities are significant market players as buyers of goods and services. Before the creation of the Internal Market, national, regional and local authorities favoured domestic suppliers. This was not only incompatible with the Treaty provisions requiring the creation of a single Internal Market but also had negative macro and microeconomic implications for the European economy (Commission of the EU 2004). Furthermore, there are indications that proper use of the directives is far from common practice. The non-compliance of the directives from public authorities is a major issue (Gelderman *et al*. 2006).

Public procurement has evolved from a primary mission of acquisition goods, supplies and services to enable public employees to successfully discharge their responsibilities into a process of facilitating the delivery of core government services by independent contractors (Wendell and Lawrence 2005). Under these arrangements, the (fragmented) public sector procures services from the private sector, including the use of the underlying assets, rather than directly providing them. Governments and their agencies are in effect becoming the producer and regulator of services rather than the provider (Shaoul 2002), which increases the number of partnerships when procuring these services. Public procurement partnerships take government procurement and contracting professions out of their comfort zones and require a great deal of individual discretion. The ability to exercise discretion is a commodity that is not shared equally by all governments and by all government procurement systems (Wendell and Lawrence 2005).

An essential aspect of public procurement partnerships is the implicit understanding that the choice of partners and the specific boundaries of the partnership relationship must be negotiated. A movement away from regulating process in favour of jointly agreed upon goals or outcomes require new and different public procurement approaches (Wendell and Lawrence 2005). Nielsen and Hansen (2001) found that the introduction of the "competitive dialogue" would be a step in the right direction of supporting rationally grounded buyer-seller relations within technically complex procurement processes. The new competitive dialogue procedure, which will be "based on" the general principles of transparency and equal treatment, will be spelt out in the directive alongside the conditions for its use (Arrowsmith 1999). This implies that the expressed rules applying to this procedure will be more detailed than those governing the competitive negotiated procedure. Provided that the new rules are themselves limited to reasonably general concepts, this could be advantageous (Arrowsmith 1999).

The introduction of a new "competitive dialogue" procedure are important in the context of public private partnerships to ensure that all award procedures for such complex contracts can be conducted in an effective manner (Arrowsmith 1999). However, due to the uncertainty in both hierarchical position in respect to other procedures and internal structure, the "competitive dialogue" may create opportunities for fraudulent post-tender negotiations and unduly reduce competition in a market (Curtol *et al*. 2006). Competitive dialogue is potentially available not merely for the sort of complex public private partnership that prompted this adoption, but also for other non-standard procurements. However, there remains some doubt over its precise application because of the uncertainties connected with the procedure of competitive dialogue (Arrowsmith 2004).

The concepts of transparency and accountability are nowhere more significant in public administration than in procurement (Schapper *et al*. 2006). Opening of public procurement national markets to the EU competition implies a series of economic and social reforms. The principal of openness, fairness and transparency are basic elements of an effective public sector, which intends to align with the mechanism of a free market (Mardas 2005) The effects of the Public Procurement Directives have been questioned ever since first adopted in the 1970s (Gelderman *et al*. 2006). Some argue that empirical evidence is consistent with the *ex-ante* expectation that the EU single market programme should have increased competition and consequently reduced market power, especially for firms operating in industries where non-tariff barriers were perceived to be high (Bottasso and Sembenelli 2001). The commission argues that an increase in cross-boarder contracts will be an indication of a well-functioning public procurement market (Sanderson 1998). Several studies, for example Cox and Furlong (1997), of possible increases of cross-border contracts in the early 1990s did not show the expected results. The reason for this is said to be faulty application of the regulations by the member states. The solution of this problem was to make member states to implement the regulation as correct, clear and easy as possible in the national context (European Commission 1996). The public sector has to recognise that an effective public procurement system implies the openness of public contracts to foreign competitors (Mardas 2005). The existence of preferential public procurement policies is a well-known fact in many countries. Favouritism in the awarding of public contracts can result from an explicit “buy local policy” when the government offers a specified preference for domestic suppliers (Mougeot and Naegelen 2005). However, if a domestic product performs well in terms of industrial and trade structures, then it can also perform well within an open non-discriminatory public procurement market against foreign bidders (Mardas 2005). The cost of not encouraging intra-EU competition is substantial. The public sector pays more than it should for goods, supplies and services it buys and, in doing so, supports sub-optimal enterprises in the European Union (Martin *et al*. 1999).

There are several reasons why the EU legislation might have failed to open-up public procurement markets to international competition (Martin *et al*. 1999). First, purchaser might be splitting up large contracts so that the value of each falls below the threshold stipulated in the procurement legislation. Second, purchasers might simply not advertise their prospective purchases even where a contract falls within the remit of the legislation. Finally, the Commission relies on others to bring cases of malpractice to its attention and plays no pro-active role in this process. Gelderman *et al*. (2006) found that educating and training public purchasers will be an effective tool for increasing the familiarity with the rules and thus the compliance with the directives.

The procurement regulation builds on neo-liberal theories, which assume that public supply efficiency is best achieved through competitive and open tendering procedures (Cox and Furlong 1997; Bovis 2006). This, for certain types of procurements and products, is apposed to other theories – see for example the first paragraph in this section. The neo-liberal theories were particularly clear in the early versions of the regulations; changes in the later versions made it possible to choose more collaborative approaches to public procurement (Bovis 2006).

National institutions, measured in terms of both quality and similarity, along with instruments of foreign trade policy, have a strong and significant impact on trade between European countries (Cheptea 2007). How the national governments choose to implement the regulations at the national level is largely decided by the political system and the prevailing business system (Bovis 2006). Three different business systems have been identified in the European Union (Winch 2000):

- Anglo-Saxon (i.e. the UK).
- Corporatist (i.e. Germany and the Netherlands).
- Étatique (i.e. France and Italy).

Sweden and Denmark would be closest to the corporatist system. The corporate system there is generally a greater willingness to intervene in the market to protect social values (Winch 2000).

There are many different strategies public agencies can adopt in order to promote competitive markets, for example, managing markets via individual contracts and transactions, managing key suppliers in strategic markets, changing capability requirements for purchasing personnel (Caldwell *et al*. 2005). Public procurement can aid the development of a sector and innovation (Edquist *et al*. 2000). Arguments for its use as an innovation policy instrument refer to its use of the market power and technological competence of large public sector organisations to reduce risks, provide incentives, articulate demand, and assure markets for producers who would otherwise hesitate to develop innovative solutions and products (Geroski 1990). Moreover, public procurement can also play a vital role in the diffusion of innovations, where the spread of a new product or system to new markets or market segments typically requires further development work in order to adapt it to these new contexts (Edquist and Hommen 2000). The distinction between ‘direct’ and ‘catalytic’ public procurement (the latter being carried out on behalf of other eventual end-users) is also highly relevant for the diffusion of innovations. With the perspective of public procurement affecting the development of a sector, a national innovation system perspective may also be used to categorise different national approaches. Four different categories have been identified (Manseau and Seaden 2001) and three of the four are present within the European Union:

- Market-driven (i.e. the UK).
- Government-led (i.e. France and Germany).
- Social-democratic (i.e. Denmark and Sweden).
- Meso-corporatist (i.e. Japan, this category is not present in Europe).

In Sweden, many clients are considered to be weak, lacking a level of knowledge that would classify them as ‘informed clients’ (NAO 2005). Uninformed clients lacks a basic familiarity with the rules, which according to Gelderman *et al*. (2006) was a major reason for the non-compliance of the directives. The design professions, in the conception stage, are also considered to have a weaker position when compared with other countries, while the contractors, at least the larger ones, are considered to have a strong position within the Swedish construction business and innovation system (Bröchner *et al*. 2002). In Denmark, it is very much the other way around, the client and the design professions, especially the architect, are considered to be strong, while the contractors are considered to be relatively weaker. According to a study made by Manchester Business School (2006), the strongest voices against current procedures for public procurement tended to focus on the distinctive characteristics of national implementations of those Directives, rather than the Directives themselves. In Sweden, the implementation was seen as particularly onerous. Industry representatives commented that much more documentation was now required, and there was a noticeably greater tendency to use lowest price as a tender selection criterion. While some viewed the greater transparency of the process as a benefit, this had led to increased costs in bid preparation, less emphasis on quality issues, and, most notably, an explosion of formal contests of the outcome of bids. These had grown from 113 to 1124 in five years (Manchester Business School 2006). This would indicate that national variations in public procurement legislations will have an effect on the efficiency of the public procurement process.

There is an identified need for developed forms of procurement and contracting allowing for an increase in innovation and development of the construction industry and its products (Latham 1994; Egan 1998; Näringsdepartementet 2000). The scope for the construction sector to continuously develop and innovate would greatly be enhanced by appropriate procurement strategies by the clients. The advantages of (a) a specific product focus, (b) an alignment of motivation and (c) a drawing on lessons from other industries are confirmed (Kumaraswamy and Dulami 2001). Something that procuring on the lowest price does not encourage.

It is the client that makes the initial decision to procure construction works and the way in which procurement takes place. This in turn influences the degree of supply chain integration and ultimately the overall success of the project (Briscoe *et al*. 2004). In construction, where there are usually many parties taking part in the project for different periods of time and with different assignments, it is not only the project areas that need to be integrated but also the parties (Moore and Dainty 2001). The client is the most significant factor in the success of supply chain integration and the client must develop practices that facilitate such integration if the construction process is to be improved. Frequent changes in the forms and terms of contract and the preference for competitive price tendering are detrimental to supply chain relationships. Practices such as the use of negotiation to secure suppliers and the development of open-book accounting practices assist in building better relationships and integration (Briscoe *et al*. 2004).

EFFECTS OF THE IMPLEMENTATION OF THE PUBLIC PROCUREMENT ACT

From the perspective of construction clients, there are some major concerns about the implementation and effects of the public procurement act. One part of the public procurement regulation is that an unsuccessful bidder may challenge the procurement process of a contract. This makes it possible to get a neutral validation of whether the procurement procedures have been correct, but it adds to the cost driving and time consuming features of the public procurement process. A study on the competitiveness of the construction sector in various countries within the EC (Manchester Business School 2006) indicates that Sweden has by far the highest number, as well as the largest increase, of contested public procurements within the EC. In Denmark, which basically has the same national business system as Sweden, there are no indications of this dramatic increase of contested public tender awards.

There are indications that both the Swedish and the Danish public agencies are more cautious in their interpretation of what is possible to do within the EU directive framework than public agencies in other EC countries (e.g. the UK), with the difference that Swedish legislators have adopted a slightly more defensive position by adding national rules. From the perspective of the public construction client, it was found that they find it difficult to follow the regulations, in both Sweden and Denmark, due to insecurity of how to interpret the benefits that exists within the directive. Thus, there is a focus on the limitations rather than on the possible benefits. In a Swedish study (NOU 1998), 50% of the clients answered that they cannot follow the regulations completely and according to the suppliers the agencies can not even follow their own evaluation models, which may be one cause for the many challenged of public tender awards in Sweden. A possible explanation for these challenges is the additional rules made in the Swedish legislation, which differs from many other EC countries (e.g. Denmark and the UK), where the EU directive has been adopted without additional legislation and rules. There is a criticism of this implementation of the public procurement directive by the Swedish client organisation as being too complex, bureaucratic and unbalanced in favour of the supplier and contractor in relation to the client. The imbalance between contractor and client can further be explained by the fact the contractors in Sweden have traditionally a stronger position than the client, which is not the case in Denmark. This imbalance in strength between the client and the supplier/contractor can result in both a higher possibility and a willingness to appeal procurement decisions in Sweden. However, in Denmark the clients have a stronger position and a majority in the board of appeals for public procurement that might have a mitigating effect on the number of challenges.

Additional national rules can further have the effect that legislation becomes too detailed and, thus, acts as a barrier for different forms of cooperation, e.g. partnering and private finance initiatives because of the belief that this kind of cooperation is not compatible with the Swedish public procurement act. This is clearly not the case in other EU countries (e.g. the UK) where this kind of cooperation between client and supplier/contractor are commonly adopted. However, in Denmark, which does not have this additional legislation to the directive, there is also some reluctance from public clients to adopt this kind of cooperation. Another aspect of too detailed public procurement rules is that the unaccustomed clients base procurement decision on price alone and do not value soft parameters in these decisions. There is a tendency for Swedish and Danish clients to make an increased effort in valuing soft parameters in the tendering process, although price still weighs heavy in the decision and evaluation process. The uncertainty in the evaluation process of soft parameters has probably added to the number of appeals. This can have the effect that if this, in general positive, development is punished with a higher degree of appeals there is a risk that clients choose the safe option of deciding on price alone.

CONCLUSIONS

Manchester Business School (2006) concluded that governmental bodies constituted an essential part in the process of change for the construction industry. As a major client in construction, governments play a key role in the use of procurement techniques, in which:

- Quality is as important as price.
- Life-cycle costing is applied to safeguard the future.
- Professional designers and consultants are properly used and selected.
- Training is ensured.
- Innovation is encouraged.
- Only properly qualified and regisetred firms and individuals are employed.
- Fair pricing and contract terms are applied.

A public procurement process and the legislation surrounding it needs to enable procurement techniques or at least not act as a barrier. The only reason for a member state to add rules and legislation to the EU directive is if it will enable a more effective and positive development of procurement techniques.

Despite similarities in their national business systems, Sweden and Denmark have adopted the EU public procurement directive differently. There are some indications from the representatives of the client organisations in Sweden and Denmark that this may have an effect on the outcome of public procurement within these countries. However, there are still perceptions in both countries of similar problems with public procurement. The main difference is the number of challenges of the public tender awards. Thus, the question is if the difference in implementation is the cause of the difference in the number of challenges.

Further studies are needed to gain knowledge of the effects of added national rules to the EU directive in relation to the transparency and effectiveness of public procurement. Does the implementation of added national legislations and rules act as barrier or as an enabler? From a client perspective, the need for further research is to map the strength and weaknesses of the public procurement in different EU countries in order to evaluate how national variations in the legislation will affect the public procurement process.

REFERENCES

Andersson, N (2003) A Mesoeconomic Analysis of the Construction Sector. *Division of Construction Management.* Lund: Lund University.

Andersson, N (2004) The Swedish construction sector: Its economic and social role. *In:* J Carassus (Ed.) *The construction sector system approach: An international framework. CIB Report, Publication 293.* Rotterdam: CIB.

Arrowsmith, S (1999) The community's legal framework on public procurement: The way forward at last? *Common Market Law Review,* **36**(1) 13–49.

Arrowsmith, S (2004) An assessment of the new legislative package on public procurement. *Common Market Law Review,* **41**(5) 1277–325.

Bottasso, A and Sembenelli, A (2001) Market power, productivity and the EU Single Market Program: Evidence from a panel of Italian firms. *European Economic Review,* **45**, 167–86.

Bovis, C (2006) *EC Public Procurement: Case Law and Regulation*. Oxford: Oxford University Press.

Briscoe, G H, Dainty, A R J, Millettt, S J and Neale, R H (2004) Client-led strategies for construction supply chain improvement. *Construction Management and Economics,* **22**, 193–201.

Bröchner, J, Josephson, P-E and Kadefors, A (2002) Swedish construction culture, quality management and collaborative practice. *Building Research and Information,* **30**(6), 392–400.

Caldwell, N, Walker, H, Harland, C, Knight, L, Zheng, J and Wakeley, T (2005) Promoting competitive markets: The role of public procurement. *Journal of Purchasing and Supply Management,* **11**(5–6**)**, 42–51.

Cheptea, A (2007) Trade liberalization and institutional reforms. *Economics of Transition,* **15**, 211–55.

Commission of the EU (2004) *A report on the functioning of public procurement market in the EU: benefits from the application of EU directives and challenges for the future,* Working Document, Directorate-General for Internal Affairs, 03/02/2004, Brussels.

Cox, A and Furlong, P (1997) Cross-border trade and contract awards **-** The intellectual myopia at the heart of the EU procurement rules. *European Journal of Purchasing and Supply Management,* **3**(1), 9–20.

Curtol, C, Pesarin, G and Vander Beken, T (2006) Testing the Mechanism on EU Public Procurement Legislation. *European Journal on Criminal Policy and Research,* **12**(3), 337–64.

Edquist, C and Hommen, L (2000) Public technology procurement and innovation theory. *In:* C Edquist, L Hommen and L Tsipouri (Eds.) *Public technology procurement and innovation.* Boston: Kluwer Academic.

Edquist, C, Hommen, L and Tsipouri, L (2000) Policy implications. *In:* C Edquist, L Hommen and L Tsipouri (Eds.) *Public technology procurement and innovation.* Boston: Kluwer Academic.

Egan, J (1998) *Rethinking Construction*. London: HMSO.

European Commission (1996) *Public Procurement In The European Union: Exploring The Way Forward*. Brussels: European Commission.

Finansdepartementet (2006) *Nya upphandlingsregle 2, SOU 2006:28*. Stockholm: Fritzes.

Gelderman, C J, Ghijsen, P W T and Brugman, M J (2006) Public procurement and EU tendering directives ? Explaining non-compliance. *International Journal of Public Sector Management*, **19**(7), 702–14.

Geroski, P A (1990). Procurement policy as a tool of industrial policy. *International Review of Applied Economics*, **42**(2) 182–98.

Kumaraswamy, M and Dulami, M (2001) Empowering innovative improvements through creative construction procurement. *Engineering Construction and Architectural Management*, **8**, 325–34.

Latham, M (1994) *Constructing the Team: Joint Review of Procurement and Contractual Arrangements in the UK Construction Industry*. London: HMSO.

Macgillycuddy, C (1988) Europe Heads for the Open Market. *Director*, **41**, 56–9.

Manseau, A and Seaden, G (Eds.) (2001) *Innovation in Construction – An International Review of Public Policies*. New York: Spon Press.

Manchester Business School (2006) *Analysis and assessment of the elements of certain Community policies that impact on the competitiveness of the construction sector*, Final Report, Contract No 30-CE-0043801/00-12, University of Manchester, UK.

Mardas, D (2005) The Latest Enlargement of the EU and 'Buy National' Rules. *The World Economy*, **28**(11), 1633–50.

Martin, S, Hartley, K and Cox, A (1999) Public procurement directives in the European Union: A study of local authority purchasing. *Public Administration*, **77**(2) 387–406.

Moore, D R and Dainty, A R J (2001) Intra-team boundaries as inhibitors of performance improvement in UK design and build projects: a call for change. *Construction Management and Economics*, **19**, 559–62.

Mougeot, M and Naegelen, F (2005) A political analysis of preferential public procurement policies. *European Journal of Political Economy*, **21**(2) 483–501.

NAO (2005) *Improving Public Services through better construction*, Report by The Comptroller and Auditor General. London: NAO.

Nielsen, J U-M and Hansen, L G (2001) The EU Public Procurement Regime – Does It Work. *Intereconomics*, **36**(5), 255–63.

NOU (1998) *Effekter av lagen om offentlig upphandling*. Stockholm: Nämnden för Offentlig Upphandling.

Näringsdepartementet (2000) Från byggsekt till byggsektor. SOU 2000:44. Stockholm.

Ramsey, L E (2006) The New Public Procurement Directives: A Partial Solution to the Problems of Procurement Compliance. *European Public Law*, **12**, 275–94.

Sanderson, J (1998) The EU Green Paper on public procurement: A better way forward or a missed opportunity? *European Business Journal*, **10**(2), 64–70.

Schapper, P R, Veiga, J N and Gilbert, D L (2006) An Analytical Framework for the Management and Reform of Public Procurement. *Journal of Public Procurement,* **6**(1), 1–26.

Shaoul, J (2002) The regulation of and accountability for new forms of public procurement, *Working Paper Series*, Paper No 17, Centre on Regulation and Competition, Institute for Development Policy and Management, University of Manchester.

Winch, G (2000) Construction business systems in the European Union. *Building Research & Information,* **28**(2), 88–97.

PERFORMANCE MEASUREMENT OF THE MAJOR PROCUREMENT ROUTES IN FINLAND

Adekunle Sabitu Oyegoke[1]

Department of Construction Economics and Management, Helsinki University of Technology, PO Box 2100, 02015 HUT, Finland

The aim of the study is to compare procurement performance in Finland based on key project performance variables. The study is based on empirical case-questionnaire studies. Construction project performance is measured via a rating system through key variables of time, budget, quality, satisfaction, contracting system, and the effectiveness of design management along procurement types. The measurement is carried out along design and construction phases. The procurement methods are categorized in accordance with the major (prevalent) routes in Finland: design and build, consulting CM, contracting CM, general contract – traditional, general contracting – separate trades. The results show that the performance attributes are shared between different routes, for instance, the design and build ranked first in responsibilities/risk distribution, design management and meeting of the project target while the contracting CM is better in completion time, quality level and equal general contracting (separate trades) in technical quality level. Conversely, the consulting CM and general contracting – separate trade ranked better in interrelationships than most routes in design and construction phases owing to their flexibilities in apportioning responsibilities to different consultants and trade (specialist) contractors.

Keywords: construction, Finland, measurement, performance evaluation, procurement.

INTRODUCTION

The performance of a procurement route depends on many organization variables as procurement route defines project organization set-up. Love *et al*. (1998) define procurement as an organizational system that assigns specific responsibilities and authorities to the people and organizations, and defines the relationships of the various elements in the construction of a project. In other words, project procurement establishes the contractual framework that determines the nature of relationship between the project team within the duration of their interactions. Different measurement methods have been used to measure project performance. Konchar and Sanvido (1998) measure quality on the basis of building element performance and Yng *et al*. (2002) use a Likert scale to measure the owner's satisfaction and administrative burden. Extensive work has been done by Samelson and Levitt (1982), Kaka and Price (1991), Russell *et al*. (1992), Kumaraswamy and Chan (1995) and Chua *et al*. (1999) on different factors that influence project performance.

The aim of this study is to compare project performance along procurement routes within Finnish practice, in order to measure their efficiency and effectiveness in relation to cost, time, quality, satisfaction, stakeholders' relationships, etc. The

[1] aoyegoke@cc.hut.fi

procurement route is categorized into five in accordance with their share and value of contract in Finland. The scope of this paper is procurement performance measurement within the selected performance variables and is limited to Finnish practice.

RESEARCH METHOD

This study is carried out by empirical studies via a case-questionnaire survey. The empirical study is carried out via a case-questionnaire to probe some recent cases of different procurement routes and to make an assessment of project performance as a whole. A self-completion case-questionnaire is used to collect both qualitative and quantitative data from experienced industry practitioners. The method adopted in this paper is to measure the identified performance variables in project procurement performance by a rating scale of 1–5 points. This is to obtain both factual and attitudinal information and understanding from different players. All the investigated projects in this study are based in Finland covering both private and public projects.

Conduct of the project case survey

The aim was to reveal the organizational set-ups and the involved parties' task-level performance in the project cases, ex post, along the five prevailing procurement routes (general contracting – traditional, general contracting – separate trades, CM contracting, CM consulting and design-and-build contracting) and the perceptions of the key project parties in the building sector in Finland. The contents of responses are analysed and authenticated through unstructured interviews. The analysis of the rating questions is done through descriptive data analysis. The aim is to have a broader view of analysing the data since a subjective-quantitative rating system is used. Out of maximum of 5 on the rating scale, 3.75 is assumed to be a reasonable performance level amounting to 75% of performance level. Variables along procurement routes are then categorized as 'measured high or low' depending on the means rating.

The project case-questionnaires were distributed to 51 professionals. Forty-two professionals responded before the closing date. Owing to the insufficiency of the data, seven questionnaires were discarded from the analysis. In other words, 35 (69%) project case-specific questionnaires were eligible that were executed between the year 1999 and the year 2005. In Table 1, the combined distribution of 35 project cases is shown by the gross floor area and the procurement route type. There are one to four projects in each category except in GC-st in (3001–6000), GC-t (6001–10 000), D-and-B contractor (10 001–15 000) and all the routes in category >15 000 except in CM contractor.

Table 1: Distribution of the projects by building size and procurement route (n = 35)

		Gross floor area (sqm)				
Route	**No.**	**< 3000**	**3001–6000**	**6001–10 000**	**10 001–15 000**	**> 15 000**
General contractor – t	8 (23%)	4	2	0	2	0
General contractor – st	6 (17%)	4	0	1	1	0
CM consultant	8 (23%)	1	3	2	2	0
CM contractor	7 (20%)	2	2	1	1	1
D-and-B contractor	6 (17%)	1	2	3	0	0
Total	35 (100%)	12	9	7	6	1

OVERALL PROJECT MANAGEMENT AMONG PROJECT CASES

The overall project management performance consists of nine variables. These variables are randomly selected by the FinSUKE research team and the author after due consideration. This group comprises experienced industry practitioners from both contracting and consulting practices as well as experienced academics. These projects are not randomly selected (selected by the respondents) but cover main procurement routes used in Finland.

- The upper-level choice of the procurement route and its effectiveness/consequences for other variables associated with the project organization set-ups.
- Early clarity in the allocation of risks and the distribution of responsibilities is one measure for high-level responsibility/risk management.
- Overall project target attainment is high level if it meets the project objectives after completion.
- Overall client satisfaction is measured high level depending on the client perception during the construction processes and completed project outcome.
- The attainment of a client's budget is measured high level if the budget is within the set targets.
- Design management is measured high level if the design is well coordinated and adds value to the processes.
- High-level technical quality of the finished products.
- Well-managed project quality as stipulated in the contract documents.
- On-time project completion attainment.

In Table 2, the overall project performance rating is shown in terms of nine variables, in descending order among the projects (n = 35). The overall mean ranking is at the level of 3.95. The mean ranking varied between 3.60 and 4.21. The rating varied between 3 and 5 points among the six variables and between 2 and 5 among the three remaining variables, i.e. budget attainment, design management and responsibility/risk management. On average, the respondents were most satisfied with the selected procurement routes (with the mean of 4.21). Project target attainment, good schedule management and client budget attainment ranked also high. Design management performance was ranked as the lowest (with the mean of 3.60) due to the late design, the insufficiency of (detailed) design documents.

Table 2: Overall project performance rating

Performance variables	Mean	1	2	3	4	5
Procurement route	4.21	–	–	4	19	12
Project target attainment	4.15	–	–	4	22	9
Completion time	4.10	–	–	6	19	10
Client budget attainment	4.06	–	2	7	13	13
Client's satisfaction	4.00	–	–	8	18	9
Quality	3.88	–	–	8	22	4
Technical quality	3.82	–	–	9	22	3

Responsibility/risk	3.76	–	1	12	15	6
Design management	3.60	–	2	13	17	3

In Table 3, the overall project performance rating is shown for each of five prevailing procurement routes among the 35 projects. The choice of the procurement route used rated best with the highest total mean value, followed by target attainment, completion time, budget attainment and client satisfaction. These are followed by quality assurance, level of technical quality, allocation of responsibilities and risks and lastly design management. The standard errors measure of uncertainty and the sample variance of the data are low. The standard deviation low results show the realiability of the ratings because the data points are close to the mean.

There are no dominant routes among the routes under survey. For instance, the design-and-build contracting system ranks first in target attainment, responsibility distribution and risk allocation and in design management. The CM consulting route is rated higher than other routes in procurement choice and overall client satisfaction but rated last in quality assurances. The separate trade traditional general contracting is rated best in technical qualities but rated last in a choice of procurement, budget attainment and client satisfaction. The CM contracting route is ranked best in completion on time, quality assurances and technical quality, but last in responsibilities/risks allocation. The general contracting route ranked better than other routes in budget attainment, but last in completion on time, quality assurances, technical quality and design management. In overall performance the design and build ranked first followed by CM-contracting, general contracting-st, CM-consulting and lastly general contracting-t.

Table 3: Comparison of the overall project performance rating along variables and procurement routes among the projects cases in terms of means (n = 35)

Performance variables	**Total mean**	**D-and-B contracting**	**CM consulting**	**General contracting-st**	**CM contracting**	**General contracting-t**
Procurement route	4.21	4.17	4.38	4.08	4.14	4.13
Project target attainment	4.15	4.50	4.00	4.33	4.00	4.00
Completion time	4.10	4.08	4.38	3.83	4.43	3.75
Client budget attainment	4.06	4.00	4.13	3.50	4.14	4.38
Overall client satisfaction	4.00	3.92	4.31	3.83	4.00	3.88
Quality assurance	3.88	4.00	3.75	3.83	4.14	3.75
Technical quality	3.82	3.80	3.75	4.00	4.00	3.63
Responsibilities/risks	3.76	4.00	3.88	3.83	3.57	3.63
Design management	3.60	4.33	3.38	3.50	3.86	3.25
Overall performance	3.95	4.09	3.99	3.86	4.03	3.82

	Project management performance variables									**Types of procurement routes**				
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*	*M*	*N*
Theme														
SE	0.05	0.11	0.14	0.15	0.09	0.08	0.07	0.08	0.20	0.07	0.08	0.11	0.09	0.11
SD	0.11	0.24	0.31	0.33	0.19	0.17	0.16	0.18	0.44	0.22	0.23	0.34	0.26	0.33
Sample Variance	0.01	0.06	0.09	0.11	0.04	0.03	0.03	0.03	0.19	0.05	0.05	0.12	0.07	0.11
Confidence Level (95.0%)	0.14	0.29	0.38	0.40	0.24	0.21	0.20	0.22	0.54	0.17	0.18	0.26	0.20	0.25

A – Procurement route; *B* – Project target attainment; *C* – Completion time; *D* – Client budget attainment; *E* – Overall client satisfaction; *F* – Quality assurance; *G* – Technical quality; *H* – Responsibilities/risks; *I* **–** Design management; *J* – Design and build; *K* – CM contracting; *L* – CM consulting; *M* – General contracting – st; *N* – General contracting – t

Responsibility distribution and risk allocation management in project cases
In Figure 1, the rating of the responsibility/risk distribution varies 3.6–4.0 among the five procurement routes. The D-and-B contracting was ranked first based on the integration of the design management with the other responsibilities and the clear risk distribution among the project parties. In the GC contracting with separate trades and CM consulting, the contractors are selected after the completed design phase and the contractors are coordinated and supervised by the general contractor or the CM consultant, respectively. CM consulting allows trade contractors to have direct contracts with a client.

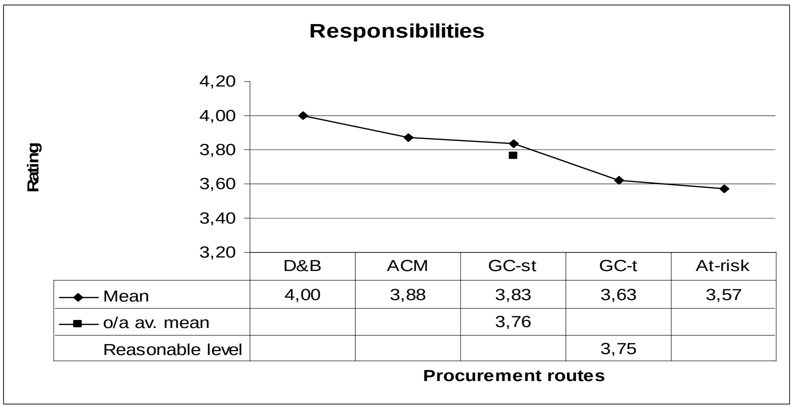


Figure 1: Risk and responsibility distribution rating by procurement routes among the projects (n = 35)

The risk-taking CM contracting was ranked the lowest route because of a lack of adequate checks and balances when a CM contractor assumes the dual role of designer and contractor during different project phases. In addition, a CM contractor carries out preconstruction management services. Uncertainty is inherent in a client's final choice between the independent contracting firm or CM contractor in the construction stage.

Many project cases were executed under an uncoordinated task approach or under a subcontracting approach with a back-to-back form of risk allocation. In such cases, the specialist contractors were responsible for their detailed mechanical and electrical drawings that were checked by the design team before the incorporation into overall design. A specialist M&E contractor is responsible for the technical risks. In practice, only a few changes and claims emerged. In addition, FM services were subcontracted to specialist contractors.

Overall client satisfaction management among project cases
In Figure 2, the overall mean of the client/owner satisfaction is shown to be ranked at the high level of 4.0. The satisfaction varied 3.8–4.3 among the five procurement routes. The CM consulting was ranked best (4.3) based on the various reasons such as the direct contractual relationships between the client/owner and the trade contractors, the reduction of the project cost owing to the elimination of the main contractors' profit and the effective competition between the trade contractors.

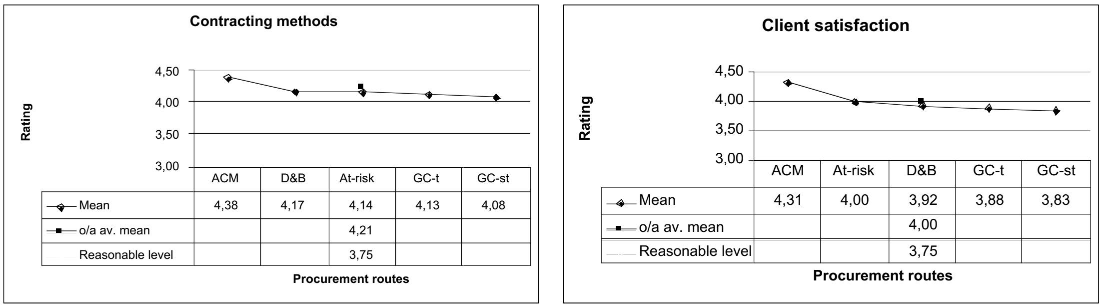


Figure 2: Contracting methods and client satisfaction rating by the procurement routes among the projects (n = 35)

In Figure 3, the overall mean of the client's/owner's budget attainment is shown to be ranked at the high level of 4.1. The budget attainment varied 3.5–4.4 among the five procurement routes. The traditional general contracting (GC-t) was ranked best (4.4) primarily due to the completeness of the documents before the actual construction works begin. Figure 3 also presents the overall mean of the client's/owner's project target attainment is shown to be ranked at the level of 4.2. The target attainment varied 4.0–4.5 among the five procurement routes. The D-and-B contracting was ranked best (4.5) followed by the general contracting with separate trades (4.3). The single point of the D-and-B contractor's performance responsibility as well as the D-and-B contractor's and the GC-st contractor's inputs in value management/engineering were mentioned to be key factors behind the high degree of project target attainment.

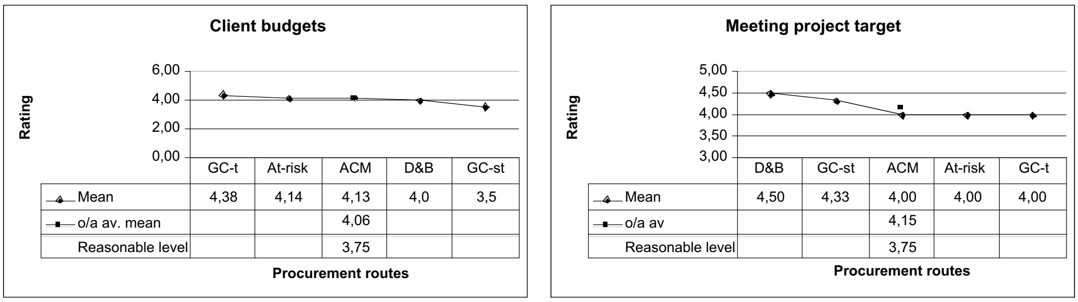


Figure 3: Client's/owner's budget and project target attainment rating by the procurement routes among the projects (n = 35)

Building design and technical quality management among project cases

In Figure 4, the overall mean of the building design management is shown to be ranked at the fairly low level of 3.6. The level of the design management varied 3.3–4.3 among the five procurement routes. The poor design management was witnessed in the case of the traditional general contracting (3.3) and CM consulting (3.4) below the overall mean and reasonable level of performance 3.75. This was due to the fact that the contractor was not involved in the design process, the overall design led to many design changes, the design documents were not ready on time and the lack of the responsibilities/penalty in the case of design mismanagement.

In four project cases, the specialist contractors or the subcontractors were acting in the capacity of the multiple prime contractors engaged in the design and construction of their section of the contracts (e.g. the structural shell, the HVAC systems). These contractors were involved early to work with the design team so that their component or work could be fully integrated with the main works. The design team provided them with the information on the functionality, the specifications and the usage of the building. The dual tendering involved the subcontractors to compete on the price, the schedule and the quality as well as on the life cycle value management as part of the FM services and the renewal. In all the four cases, the main contractor coordinated the construction works and the design team provided project management and administration services.

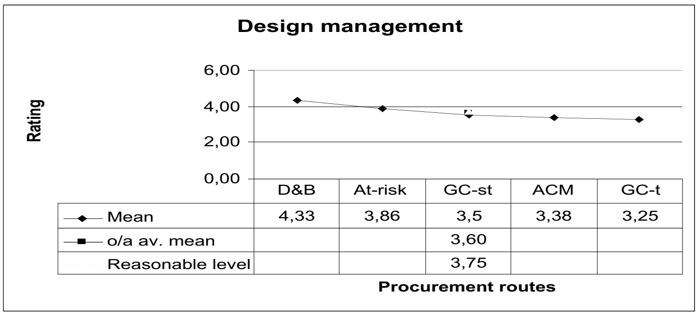


Figure 4: Design management rating by the procurement routes among the projects (n = 35)

In Figure 5, the overall mean of the project quality assurance is shown to be ranked at the fairly low level of 3.9. The level of the quality assurance varied 3.8–4.1 among the five procurement routes. The risk-carrying CM contracting was ranked best (4.1) followed by the D-and-B contracting (4.0), owing to the both contractor's involvement in the preconstruction phase and the value engineering management. Also in Figure 5, the overall mean of the technical quality level is shown to be ranked at the fairly high level of 3.8. The level of the technical quality varied 3.6–4.0 among the five procurement routes. The general contracting with separate trades (GC-st) and the risk-carrying CM contracting were ranked better (4.0) than the other routes in managing the technical quality. In the former case, the separate trade contractors contributed markedly already in the design phase (some of them even carried out the design work).

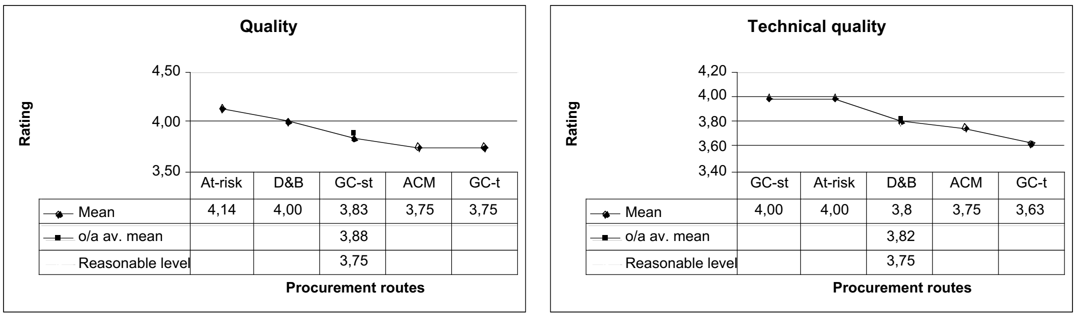


Figure 5: Project quality assurances and technical quality rating by the procurement routes among the projects (n = 35)

Schedule management among project cases

In Figure 6, the overall mean of the project schedule management is shown to be ranked at the high level of 4.1. The level of the schedule management varied 3.8–4.4

among the five procurement routes. The risk-carrying CM contracting was ranked best (4.4) because of the involvement of the CM contractor in the preconstruction and construction phases adding more value in the constructability, the early construction decision making and the trust among the other project parties.

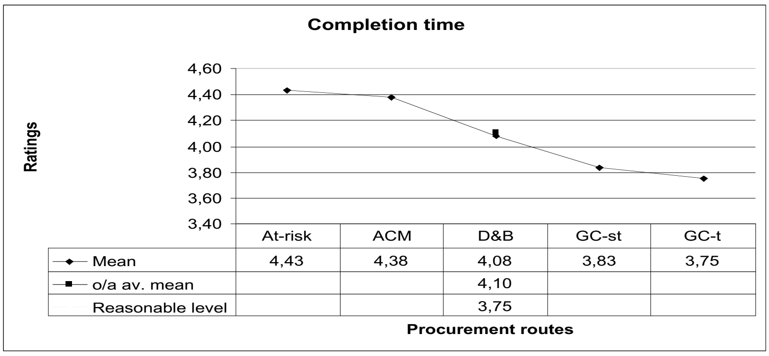


Figure 6: Completion time rating by procurement routes among the project cases (n = 35)

RESULTS SUPPORTING THE PREVALENT PROCUREMENT ROUTES

In procurement routes, the variance between the highest and the lowest is 0.30 points. The CM consulting route has 4.38 points, with the lowest point of 4.08 for general contracting. The variance in project target attainment is 0.50 points, with the highest in the design-and-build route (4.50) and the lowest in CM consulting, CM contracting and GC-t. The CM contracting rated higher than the other routes in completion on time (4.43) while the GC-t has 3.75 points. The GC-t has a higher rating in budget attainment (4.38) while GC-st has lowest rating (3.50). The clients are more satisfied with CM consulting route (4.31) but less satisfied with GC-t (3.88). Project quality assurance is more pronounced in CM contracting (4.14) but less in CM consulting and GC-t (3.75). The GC-st and CM contracting are higher in technical quality (4.00) while CM consulting is lower (3.75). Both performance risks and project responsibilities are well defined in the design-and-build route (4.00) but less defined in CM contracting (3.57). In design management, the design-and-build route has 4.33 points while GC-t has 3.25 points. In overall performances, the design-and-build is better than the other routes (4.09) followed by CM contracting, CM consulting, GC-st and finally GC-t.

The results of the survey indicate the fact that each procurement route has its strengths and weaknesses in such terms as the nine project management variables. This supports the previous notion that there is no single procurement route that suits best to all kinds of building projects:

- The D-and-B contracting was evaluated to be best in design management, responsibility and risk distribution and project target attainment.
- The CM consulting was evaluated to be best as procurement route and in achieving high client satisfaction.
- The general contracting with separate trades (GC-st) was evaluated to be best in managing high technical quality.

- The risk-carrying CM contracting was evaluated to be best in the tight project schedule management, high project quality assurance and equal GC-st in technical quality level.
- The traditional general contracting (GC-t) was evaluated to be best in attaining the client budget.
- In overall performance, the design-and-build ranked first followed by CM-contracting, general contracting with separate trades (GC-st), CM-consulting and lastly traditional general contracting (GC-t).

Table 4 presents results supporting the prevalent procurement routes. In overall project performance the prevalent routes are above reasonable level of performance of 3.75 in most of the variables.

Table 4: Results of the project cases survey supporting the prevailing routes at above 3.75 performance level

Variables	Results supporting the other procurement routes
Overall project performance management	Target attainment, completion on time, budget attainment, quality control and management, technical quality attainment, proper distribution of responsibilities and risks, and better design management
Responsibilities/ risks allocation	D-and-B (4.00) Single point of performance responsibilities and risk on non-performance
Relationship management	Direct contract with the owner as in the CM consulting, single point of responsibility as in D-and-B, and with a separate trade contractor, and multiple points in implementation as in CM consulting
Overall client satisfaction	CM consulting (4.31) The direct contractual relationships between the client/owner and the trade contractors as well as the cost reduction due to elimination of a layer of profit
Client target attainment	D-and-B (4.50) Clarity in defining owner's requirement through project performance specifications
Client budget attainment	GC-t (4.38) Larger contingency amount that covers design and the completion of the working documents before the construction works begins
Building design management	D-and-B (4.33) Single point of design and construction responsibilities and performance risks
Project quality assurance	CM contracting (4.14) The contractor's involvement in the preconstruction phase and the value engineering management
Technical quality management	GC-st and CM contracting (4.00) Specialist involvement via competition in design and construction works
Project schedule management	CM contracting (4.43) based on the integrative involvement of the CM contractor

Table 5 shows some of the areas where there are problems in prevalent routes: unclear definition of responsibilities as in GC-st, non-involvement in design as in GC-t contractors, clash of interest as a consultant and contractor as in CM contracting.

Table 5: Results of the project cases survey below reasonable level of performance 3.75

Variables	Prevalent routes below reasonable level of 3.75
Client budget attainment	The GC-st route has a rating of 3.50 because of unclear responsibilities (prime and subcontractor) leading to management problems between the main contractor and separate trade contractor
Technical quality	The GC-t has a rating point of 3.63 because of the main contractor's non-involvement in design and blame shifting between the designers
Responsibility/risks	The CM contracting has a lowest rating point of 3.57 owing to its clash of

management	interest as a consultant and contractor. The GC-t has a rating point of 3.63 owing to uncertainty associated with the design and construction works (value engineering and management)
Design management	The three variables (GC-t 3.25, CM consulting 3.38, GC-st 3.50) suffer from lack of involvement in design process (except separate trades contractors), insufficiency of design and lack of value engineering and management

In the area of responsibility distribution and risk allocation among project parties, many project cases were executed under an uncoordinated task approach or under a subcontracting approach with a back-to-back form of risk allocation. Across the separate trade contracts, the separate trade contractors were responsible for their detailed drawings and technical risks. This gave encouragement to innovate and to raise the quality standards. For example, one specialist contractor in one of the cases suggested the adoption of a self-supporting glass wall that reduced the external wall area markedly. In the area of project party relationship management, the relationships between the client/owner and the designers as well as between the client/owner and the contractors were managed best in the design phases under CM consulting. In turn, the relationships between the client/owner and the contractors were managed best in the construction phases under D-and-B contracting. Multiple direct contracts with a client/owner seem to be free of conflicts and, thus, beneficial to the whole building process. In turn, the two GC contracting routes were ranked best in managing the relationships between the contractor and the subcontractors.

In the area of overall client satisfaction, the CM consulting was ranked best based in part on the direct contractual relationships between the client/owner and the trade contractors as well as the cost reduction. In the area of client budget attainment, the traditional general contracting was ranked best in attaining the client's budget because the working documents are completed before the construction works begin. In the area of building design management, many separate trade contractors and subcontractors acted as the multiple prime contractors engaged in the design and construction of their section of the contracts. The main contractor in some of the cases coordinated the construction works and the design team provided project management and administration. This is more evident in the design-and-build route because of the single point of design and construction responsibilities and risks. There were no major strains between the stakeholders in communication, cooperation and coordination throughout all the project phases.

In the area of technical quality management, the general contracting with separate trade contractors contributed markedly to the design phases (some of them even carried out the design work). In the area of project quality assurance, the CM contracting and the D-and-B contracting were ranked best because of the contractor's involvement in the preconstruction phase and the value engineering management. In the area of project schedule management, the CM contracting was ranked best based on the integrative involvement of the CM contractor.

CONCLUSIONS

Most of the measured variables performed above the reasonable performance level. The ranking order of the variables along procurement routes shows that there is no dominant route, as best performances are shared between different routes. This finding supports the influence of the relationship between management and environmental factors as a major contributor to the success of a procurement route. The study shows the weakness of four project management performance variables that are measured below the reasonable performance level in some of the procurement routes: the client target attainment, the attainment of technical quality, the distribution and allocation responsibility and risk, and the design management.

In ranking order of the means, the design-and-build route performed better than other routes because of its integrated nature of performance and design management attributes. The CM consulting ranked second because of its fragmented nature of execution process and direct contractual link with the client. The combination/improvement of these attributes from integrated and fragmented procurement spectrum could be used to re-engineer contracting processes either in the form of modification of the existing routes or by development of a newer route. This should take into account the fragmentation of the process through the involvement of many first-tier specialist contractors. Each of the specialist first-tier contractors will then utilize the integration process by carrying out design through to construction of their specialist trade (facility management optional). This will potentially prevent insufficiency of design, unclear responsibilities and lack of value engineering and management as shown in ‘low’ measured results.

REFERENCES

Chua, D K H, Kog, Y C and Loh, P K (1999) Critical success factors for different project objectives. *Journal of Construction Engineering and Management*, **125**(3), 142–50.

Kaka, A and Price, A D F (1991) Relationship between value and duration of construction projects. *Construction Management and Economics*, **12**(1), 112–20.

Konchar, M and Sanvido, V (1998) Comparison of US project delivery systems. *Journal of Construction Engineering and Management*, **124**(6), 435–44.

Kumaraswamy, M M and Chan, W M (1995) Determinants of construction duration. *Construction Management and Economics*, **13**, 209–17.

Love, P E D, Skitmore, M and Earl, G (1998) Selecting a suitable procurement method for a building project. *Construction Management and Economics*, **16**, 221–2.

Russell, J S, Hancher, D E and Skibniewski, M J (1992) Contractor prequalification data for construction owners. *Construction Management and Economics*, **10**, 117–35.

Samelson, N M and Levitt, R E (1982) Owner’s guidelines for selecting safe contractors. *Journal of the Construction Division, ASCE*, **108**(C04), 617–23.

Yng, F L Y, Lean, C S, Wai, E C C, Ping, E L and Min, L (2002) *Performance evaluation of alternative project procurement methods*, Project Report, National University of Singapore.

GOVERNANCE OF PERFORMANCE OF BUILDING SERVICES DESIGNERS IN DESIGN AND BUILD CONTRACTS

Francis W.H. Yik[1] and Joseph H.K. Lai

Department of Building Services Engineering, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong SAR, China

The work reported in the paper is a preliminary study for informing a conceived study that aims to enhance performance of building services design professionals in Hong Kong. The reasons for conducting such a study and for basing the study on design and build (DB) projects are explained in the paper. The preliminary findings suggest that factors that are conducive to better performance of building services designers in DB projects include: DB contractors' demand for high standards in schematic design for winning contracts by bidding; DB contractors' willingness to pay higher design fees; more stringent design-checking procedures; any design-related rework at the expense of contractor; higher level of design liability beyond reasonable skill and care; and more active participation by contractors in design management and services coordination. However, there are obstacles to wider adoption of DB in the Hong Kong construction industry, especially the regulatory control in force.

Keywords: building services designer, design and build, Hong Kong, liability, performance governance.

INTRODUCTION

When contractors are under pressure to finish a construction project within a specified timeframe and at an agreed price, work quality could be sacrificed (Chini and Valdez 2003). However, contractors are not the only party to be blamed for project time and budget overruns and poor construction quality. Research has revealed that many such problems can be traced back to the problem of the quality of design, such as errors, incompleteness and lack of constructability, and to poor contract administration and lax supervision by design consultants (Tan and Lu 1995). Love and Li (2000) found that design-related rework accounted for 72% of the total rework costs in two building projects. A similar finding is reported in Koskela *et al*. (2002), together with the deficiencies in design management, including the deficiencies in client's brief, frequent design changes and lack of planning of design consultants.

For building projects, architects are often held responsible for productivity and quality problems owing to their lack of construction knowledge (Fox *et al*. 2002). As to building services installations, which are commonly regarded as specialist works and procured through subcontracting, many contractual and in-use performance problems are due to flawed designs, fuzzy demarcation of responsibilities between services designers and subcontractors (Parsloe 1997), and lack of adequate consideration given to testing and commissioning and operation and maintenance during design (Mantai

[1] bewhyik@polyu.edu.hk

2006). The consequences of unsatisfactory performance of building design professionals (including architectural, structural and building services consultants), such as latent defects, can incur huge economic losses, not only to building owners, contractors and subcontractors but also to themselves in case they are held liable for negligence and the damage exceeds the protection they have through professional indemnity insurance (Bateson and Mak 2000).

Many building construction projects procured using the traditional design–bid–build (DBB) procurement system are plagued with the above-mentioned problems. Since the 1980s, the design and build (DB) system, including its various variants (Akintoye 1994; Ng and Skitmore 2002), is increasingly used for procurement of construction projects in many parts of the world for both private and public sector projects (Akintoye 1994; Ndekugri and Turner 1994; Songer and Molenaar 1996; Molenaar *et al*. 1999), including in Hong Kong (Chan 2000). This trend is expected to continue (Yates 1995; Lam *et al*. 2004).

Historical reviews (Agostini 1996; Songer and Molenaar 1996; Konchar and Sanvido 1998; Pietroforte and Miller 2002) show that the resurgence of DB (ancient master builders being the original design/builders) was mainly due to project clients' dissatisfaction with the DBB procurement system (the dominant system since the early 20th century), especially in respect of frequent occurrence of claims owing to incomplete, belated and erroneous designs, and conflict and disputes among contract parties, which may entail costly litigation (Yates 1995). Under a DB contract, not only the design/builder assumes single-point responsibility, the liability of both the designer and the builder increases (Ndekugri and Turner 1994; Agostini 1996; Chan and Yu 2005), which is one of the major reasons for clients to choose DB contracts (Scriven 1996).

Research studies on the performance of DB projects reveal that DB is effective in reducing project time and cost, variation orders owing to incomplete/erroneous designs, administrative task of owners, and in minimizing legal entanglements (Akintoye 1994; Yates 1995). Research findings on the impact of DB on work quality, however, are inconclusive; some showed that DB can lead to improved construction quality (e.g. Konchar and Sanvido 1998; Molenaar *et al*. 1999) while some others showed that it cannot (e.g. Akintoye 1994). Nonetheless, there is evidence that DB can be used for most sizes of project provided the client is experienced (Ndekugri and Turner 1994), and clients' experience with DB projects was generally positive (Molenaar *et al*. 1999).

Besides DB, other measures for enhancing construction project performance have been used, such as the requirements for designers and contractors to be ISO 9000 certified (Chini and Valdez 2003) and for buildability assessment (Fox *et al*. 2002); alternative dispute resolution methods (Cheng *et al*. 2004); partnering (Latham 1994); etc. More recently, measures such as design quality indicator (DQI) for measuring design quality (Gann *et al*. 2003) and post-occupancy evaluation and 'soft landings' for providing feedback to design (Way and Bordass 2005) are being advocated.

THE NEED FOR STRENGTHENING GOVERNANCE OF PERFORMANCE OF BUILDING SERVICES DESIGNERS

Although numerous research studies that aimed to enhance the processes and outcomes of construction projects can be found in the literature, very few embraced or dealt specifically with building services, apart from treating services works generally as specialist subcontract works (e.g. Hughes *et al*. 1997). Experience of assessing energy performance of new and existing buildings under the environmental assessment scheme HK-BEAM (Burnett *et al*. 2004), building energy audit and plant performance evaluation studies (e.g. Yik *et al*. 1998), and studies on specialist subcontracting practices in Hong Kong (Yik *et al*. 2006) showed that, for building developments that adopt the traditional DBB procurement system:

- At the stage of tendering, building services system designs may remain incomplete, which is a characteristic nature of specialist works (Yik *et al*. 2006). This is inevitable if the design is dependent on the characteristics of components and equipment, which will become known only after subcontractors are appointed and their offers are confirmed. For example, discharge pressures of chilled water pumps cannot be ascertained until pressure drops across chillers, air-handling units, valves and pipe fittings are known. Some building services consultants hold that tender specifications and drawings are meant to provide subcontractors with an indication of the scope of work and the performance required of the subcontract works; subcontractors are required to 'complete' the design while preparing shop drawings and other submissions for their approval (Yik *et al*. 2006). This, however, blurs the demarcation of design liability between the consultant and the subcontractor (Parsloe 1997), and is thus prone to dispute.
- Design work is often done within a limited time, based on assumed design parameters and rules of thumb, which the designer may not have time to come back and verify. Few designers are well equipped with knowledge and skills for detailed building performance simulation for in-depth design evaluations. Hence, design mistakes and omissions, and oversized plants can often be found (Yik *et al*. 1999). The introduction of building environmental performance assessment should have encouraged greater use of simulation tools in design, e.g. building energy modelling, but observations made in HK-BEAM assessments are similar to the finding of Mantai (2006) for projects assessed under the US LEED scheme: 'what we typically see is that the design choices are completed first, then the energy modelling is completed merely to document the number of LEED points'.
- All-embracing clauses like: 'the subcontractor shall supply and install …, as stipulated in the Specification and shown on the Drawings, including any additional … as are required to complete the work to the satisfaction of the Architect', 'in the event of anything … which is omitted from the Specification, the Contractor shall execute and provide all such works and things according to the direction of the Engineer or his representative', etc. are often used in contract documents, to hold subcontractors responsible for design omissions/mistakes and contingent situations, and thus to transfer design liability to subcontractors (Yik *et al*. 2006).
- Participation of design consultants in site coordination and testing and commissioning (T&C) of services systems is often inadequate while T&C skills of subcontractors are generally weak.

Clearly, besides the knowledge and skills of building services designers (and subcontractors), there is a need to enhance the existing mechanisms, including institutional, contractual and management measures, for better governance of the performance of building services design engineers (and perhaps other building design professionals as well).

THE APPROACH

With the intention of identifying effective measures for better governance of the performance of building services design professionals in Hong Kong, it is anticipated that some could be found by examining the ways in which clients and contractors of DB projects ensure designers would perform adequately. This is on the premises that:

- The client is keen to ensure that the schematic design on the basis of which the contract is awarded, and for which the amount of money to be paid has been committed, is adequately developed and the construction works for its realization are adequately executed such that he will eventually get an end-product that fits his intended purpose.
- As a DB contractor has overall responsibility for both design and construction of the entire project, he has the contractual obligation as well as financial incentive to ensure building services systems are adequately designed, coordinated, installed, and tested and commissioned to meet the client's requirements, and will be completed on time and within budget.
- Therefore, both the client and the DB contractor will make efforts to monitor the progress and quality of design works, which collectively should be more stringent than what a project client will do in the case of a DBB project.

It is reasonable to expect that a DB contractor will closely monitor the performance of his designers because he has to shoulder the design liability as well as the extra liability arising from combining design and construction under a single contract. In the case of a traditional DBB project, the contractor is liable only if his performance deviates from project plans and specifications or from the standards of good workmanship (Agostini 1996), while the liability of the client's design consultants is limited to 'reasonable skill and care' (Songer and Molenaar 1996; Gaafar and Perry 1998). A DB contractor, however, is liable for defective project-related conditions irrespective of whether the project was designed in accordance with industry standards or whether the work was performed in accordance with the plans and specifications (Agostini 1996), i.e. he is liable for 'fitness for purpose' (Ndekugri and Turner 1994), although this term is not legally well defined (Gaafar and Perry 1998; Chan and Yu 2005). Liabilities may also be implied by relevant statutory provisions, such as the Sale and Supply of Goods Act in the UK (Scriven 1996; Gaafar and Perry 1998). In Hong Kong, the relevant legislative provisions are the Sale of Goods Ordinance (Cap 26) and the Supply of Services (Implied Terms) Ordinance (Cap 457) (Cheng *et al*. 2004).

Whereas a higher level of design liability is a strong driving force for adequate performance, there is a practicality problem in that insurance to cover design liability for 'fitness-for-purpose' can hardly be obtained (Ndekugri and Turner 1994; Gaafar and Perry 1998; Chan and Yu 2005). It is therefore important to have the liability of a DB contractor clearly defined in the contract to reflect the intention of the contract parties (Scriven 1996), taking into account that there is in fact a spectrum of liability between 'reasonable skill and care' and 'fitness for purpose' (Gaafar and Perry 1998). However, even the DB contractor's liability for design problems is laid down as the 'average level of skill and care' standard, as Friedlander (1998) pointed out: 'it is rare for the standard of care to permit a design that does not achieve its intended results, … it is difficult to maintain any distinction between a design that is negligent and one that simply fails to function properly after other possible causes of the failure, such as improper construction or improper operations, are ruled out'.

THE STUDY METHOD

Apart from building services works, many aspects of DB projects in Hong Kong have already been extensively studied by local researchers. They found that in Hong Kong, DB projects are dominated by public sector projects (Chan 2000; Chan *et al*. 2001, 2002; Lam *et al*. 2004; Chan and Yu 2005) (see further discussion below). For public building projects (other than public housing projects), the Architectural Services Department (ArchSD) is the major agency that acts as the project client on behalf of the government. All such public building projects use the same general conditions of contract which are publicly available (HKG 1999a; Chan 2000; Chan and Yu 2005) and are managed by the client in a similar manner.

Given the extensive work already done by local researchers, the major information gap to be filled is the role and practices of building services consultants in the schematic design, design development and approval, and work execution stages of DB projects, which is an area where little research has been done. By focusing on public DB building projects commissioned by ArchSD, which represent the dominant type of DB building projects in Hong Kong and are managed by a single client organization following more or less standardized procedures, representative information can be obtained through in-depth discussions with an experienced building services consultant. For this purpose, meetings were held with a practising consulting engineer, who is director of a leading local building services consulting firm, and from whom sufficient information to meet the objective of the preliminary study was obtained.

The findings of the preliminary study, reported in the forthcoming section, were consolidated from an extensive literature review and desktop studies; the investigators' collective experience with the local construction industry gained from professional practices and through other relevant research studies; and in-depth discussions with the practising consulting engineer. Before the meetings for 'brainstorming' and 'information mining' were held, a list of questions on the following issues, which were regarded as critical factors influencing services designers' performance, was prepared to guide the discussions:

- objective, scope and programme of work of building services consultant;
- procedures used by DB contractor/client for vetting and acceptance of designs;
- consultancy fees;
- subcontracting, supervision and coordination of services works;
- design changes and variation orders;
- consultant's liabilities for design and installed works.

For each of these issues, how it would differ if the traditional DBB procurement system was used instead was discussed. Two rounds of meetings were held; each lasted for about three hours. The meetings were recorded such that the investigators would not be distracted by the need to jot down notes, while no important information would be lost. After each meeting, notes were prepared based on the audio record and distributed to all participants to ensure correctness of the notes and to allow each participant to provide supplements.

SERVICES DESIGN DEVELOPMENT AND WORK EXECUTION IN DB PROJECTS IN HONG KONG

Variants of DB system

Depending on the client's intention, his experience with the project nature, complexity of the project and workload on the client's in-house design team, the client may use his own design staff or commission a services consultant to produce schematic designs and prepare the relevant client's requirements for various trades of services works (such as heating, ventilating and air-conditioning, electrical, fire, lift and escalator, and plumbing and drainage installations). The services design completed at the tender stage may vary from a minimal level, in which case there will be comprehensive specifications of provisions and functional requirements for the DB contractor to fulfil (close to pure design–build), to about one-third of the whole design work (basically develop and construct). The latter case is often found in special projects that have to meet complex and highly specific end-user requirements (e.g. hospitals (Chan 2000)). If a consultant is appointed for schematic design, he will also be commissioned to evaluate tender submissions, but will not be allowed to team up with a DB contractor to bid for the project.

A certain amount of double-handling of design work exists (by the client's and the tenderer's designers); the more so the more design work is completed prior to tendering. Novation of consultants, which can avoid such abortive work, had been used before (e.g. in the HK$1.8 billion Sheung Shui Slaughter House project completed in 1999) but it is rarely used now, probably because of the awareness of the potential problems with novation (Ng and Skitmore 2002).

Contract requirements

Subcontracting the design element of the works under a DB contract is expressly permitted (HKG 1999a). Where an independent design consultant is appointed, the independent consultant shall execute under seal and provide to the client a warranty of his performance. There is an optional provision in the General Conditions of Contract for Design and Build Contracts (HKG 1999a) which requires the DB contractor to appoint, at his own expense and subject to the client's approval, an independent design checker who has the responsibility to check the designs developed after contract award against the tender offer and the client's requirements, and to certify compliance. For building services works, the checker will typically be a separate building services consulting firm. Furthermore, the design checker has to execute under seal and provide to the client a warranty of his performance. As part of the design-checking procedures, the DB contractor has to obtain the client's consent before commencement of any part of the works.

In the case of a traditional DBB contract, the contractor is not responsible for the design of the permanent work or any temporary work designed by the architect, except as may be provided for in the contract (HKG 1999b). Under the General Conditions of Contract for Design and Build Contracts (HKG 1999a), the contractor shall be liable for any defect or insufficiency in the design of the works as would an appropriate professional designer (i.e. for reasonable skill and care), and shall not be obliged to ensure the design is fit for the purpose intended by the contract. However, it is also provided that: ‘where the Employer has relied upon the Contractor to select Plant and materials required by the design to be incorporated in the Works, the Contractor shall ensure that all such Plant and materials are reasonably fit for the purpose intended by the Contract’. For building services systems, selection of plant and materials is part of the design work. Furthermore, it is hard to conceive any services system equipment and components which the client does not rely on the DB contractor to select. It follows that although the design liability to be shouldered jointly by the DB contractor and his services consultant may not be strictly up to ‘fitness for purpose’, it is higher than what the designer and the contractor would be liable for individually in the case of a traditional DBB project.

Tendering and bidding

The tendering method and procedures (pre-qualification, two envelopes for separate technical and price submissions, and bid evaluation based on overall score of technical proposal and price) have already been reported by others (e.g. Chan and Yu 2005). Increasingly, greater emphasis is put in tender assessment on innovative and/or unconventional design features that can enhance building energy and environmental performance. In this respect, the building services consultant has a key role to play. As achieving a high score in the technical assessment may allow a contractor to win the contract even if his tender price is not the lowest, DB contractors will prefer to appoint services consultants who are better equipped to embrace such design objectives in their design. Consequently, the fees that services consultants can get for DB projects are generally higher than for traditional DBB projects of comparable sizes.

DB contractors in Hong Kong are basically general building contractors and hardly any of them have a full-fledged in-house design team. When they bid for a DB project, they will call upon their preferred architectural, structural, building services and other consulting firms to form a design team, and will demand exclusivity from the consultants, but may not select services subcontractors at this stage. DB contractors will take an active role in sourcing for major services components and equipment while the services consultants will adapt their schematic designs to suit the selected components and equipment. The services consultant will be required to explore various alternative designs, for striking an optimal balance between fulfilment of specific requirements of the client (e.g. functional requirements and those on energy efficiency, environmental performance, etc.), impacts on architectural and structural designs, constructability and cost. DB contractors will pay the consultants a fee even if they lose in the bidding, although the fee may be insufficient to fully compensate for the costs incurred to the consultants. The conditions of appointment for subsequent stages of design work are often negotiated, but a firm agreement may not be made until the DB contract is awarded.

Design development and work execution

After contract award, the DB contractor will work out a master programme for the project for the client’s approval, which will lay down the milestone dates for completion of the design development works by the consultants, compliance checks and certification by the independent design checker and for achieving client’s approval in principle (AIP) and detailed design approval (DDA). The DB contractor will also negotiate and make contracts with subcontractors. Compared to a traditional DBB project, services works tend to be subdivided into smaller packages; the DB contractor will handle purchases of major services components and equipment (e.g.

chillers) from vendors direct while services subcontracts will cover on top of the installation work, supply of other materials.

During the design development stage, the DB contractor may require the services consultant to conduct further alternative design evaluation studies but, at this stage, the major objective will be for cost minimization or enhancing constructability. In this stage, the client should provide and confirm detailed requirements on services provisions for the consultant to incorporate such requirements in the detailed designs.

Subsequent to obtaining DDA, construction work may proceed and the client will refrain from making further requirement changes, unless absolutely needed. The consultant's workload will drop whereas subcontractors will start preparing shop drawings and proceed with installation works. During the construction stage, the DB contractor will assume an active role in coordination of building construction and services installation works, but will call upon the consultant to check and certify works completed (for payment claim purpose) as well as testing and commission procedures and results.

COMPARISON OF DB WITH DBB

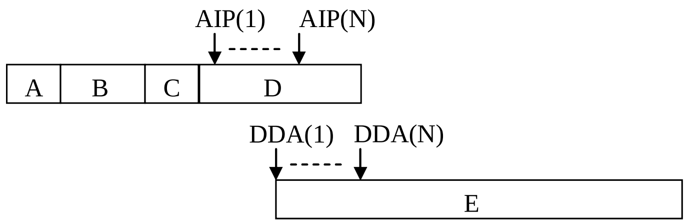
In DB projects, the design consultants work towards two different design objectives during the bidding and the post-contract-award stages. In the bidding stage, the objective of the schematic design is to achieve high standards so as to increase the DB contractor's chance of winning. Once the contract is awarded, realizing the proposed designs becomes a contractual obligation of the DB contractor. The involvement of an independent design checker helps ensure this will happen. However, after contract award, cost minimization becomes one of the key design objectives. This explains why work quality of DB projects can be better or no better than traditional DBB projects, which depends on the client's requirements, the weight given to the technical assessment relative to the weight for tender price in assessing tenders, and the rigour of the design checking and approval procedures and site inspections.

Figure 1 shows a comparison of the time span of various stages of a DB project against a traditional DBB project. Compared to a DBB project, consultants are, generally, given less time (in total) for completing the schematic design and, after contract award, also the detail design for a DB project, while the total amount of design work could be more. Owing to the different work styles required of design engineers for DB and DBB projects, some consultancy practices have set up a dedicated division for handling DB projects. The construction programme may be shortened through using DB mainly because of the better integration of designs with plant and equipment and construction/installation methods from the outset, and the earlier work commencement permitted by overlapping detailed design with construction work execution.

In a DB project, the client will not pay nor will grant extension of time for any extra works that are due to incomplete design or design errors, which is a strong driving force for the DB contractor, and a pressure on the consultant, to ensure such design deficiencies are minimized. Errors and omissions may also be identified by the independent design checker. There will be much fewer variation orders due to changes in clients' requirements after detailed design approval is granted, because such changes will incur more serious impacts on project time and cost. Also, there are fewer coordination problems, owing to the much greater involvement of the DB contractor in the process. All these factors are conducive to completion of the project on time and within budget.

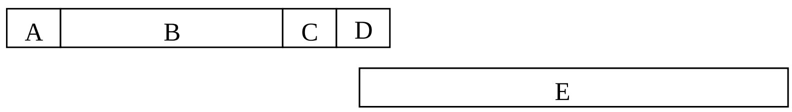
In summary, the incentive for building services designers to turn out quality designs and the measures for governing their performance may both be stronger in DB projects than in conventional DBB projects. Nevertheless, inexperienced clients, an unclear brief, insufficient time allowance for schematic design and detailed design development, and the attempt by contract to minimize cost after contract award are unfavourable factors that could undermine design quality.

(a) **Design and build project**



A – Project inception, tender documents, pre-qualification
B – Tendering, schematic design (≈3 months)
C – Tender evaluation and contract award
D – Design development (≈6 months)
E – Shop drawings and construction/installation
AIP – Approval in principle; entire works broken down into N parts in the process
DDA – Detailed design approval

(b) **Traditional design-bid-build project**



A – Project inception, selection of consultants
B – Scheme design, design development and tender documents (≥12 months)
C – Tendering, tender evaluation and contract award
D – Shop drawings and permission for commencement of works
E – Construction

Figure 1: Project programme for building development: (a) design and build project; and (b) traditional design–bid–build project

LIMITED USE OF DB IN PRIVATE SECTOR IN HONG KONG

The limited use of DB by private sector clients in Hong Kong may be ascribed to the following reasons:

1. The Building Regulations (Cap 123) in force in Hong Kong, which evolved around the traditional DBB procurement system, are hindering adoption of DB in private sector projects. The Regulations provide that construction work may commence only if all the required consents have been obtained, which require submission of a full set of building plans, structural and drainage design drawings and calculations. Hence, the benefit of overlapping the design and construction processes for shortening project duration, which is one of the major advantages of DB, is not attainable. Furthermore, the ‘authorized person’ (typically the architect or structural engineer), who is responsible for

dealing with the Building Authority on matters regulated by the Building Regulations as well as for supervising, checking and sanctioning the contractor's work, will have difficulties in discharging his statutory duties when he is employed by the DB contractor as his design consultant (Chan and Yu 2005). Public work projects, however, are exempt from this legislative control, which explains why public work projects dominate among buildings that are procured using DB contracts (Chan 2000).

2. It is a common perception that the DB procurement system tends to turn out unimpressive buildings with just average construction quality, notwithstanding that this has been shown to be not necessarily true (Ndekugri and Turner 1994; Chan *et al*. 2002). For removal of this obstacle, contractors who have good experience and skills in undertaking DB projects and wish to expand their DB business have to demonstrate to potential clients the benefits that clients can get by adopting DB. This, however, will be possible only if the Building Regulations are amended to remove the above-mentioned hurdles.

CONCLUSION

The preliminary findings suggest that factors that are conducive to better performance of building services designers in DB projects include: DB contractor's demand for high standards in schematic design for winning contracts by bidding; DB contractor's willingness to pay higher design fees; more stringent design-checking procedures; any design-related rework at the expense of contractor; higher level of design liability beyond reasonable skill and care; and contractor's more active participation in design management and services coordination. However, there are obstacles to wider adoption of DB in the Hong Kong construction industry, especially the regulatory control in force. Despite the fact that there are factors that may adversely affect design quality in DB projects, the work provided prima facie evidence that researching into DB projects will be worthwhile and should form a significant part for an in-depth study that aims to find out how performance of building services designers can be enhanced.

ACKNOWLEDGEMENT

The authors are indebted to the interviewee who shared his knowledge and experience with them, which was crucial to this study.

REFERENCES

Agostini, J (1996) Legal aspects and risk management of design/build contracts. *Architects/Engineers Professional Network*, available at http://www.aepronet.org/pn/vol9-no1.html.

Akintoye, A (1994) Design and build: a survey of construction contractors' views. *Construction Management and Economics*, **12**, 155–63.

Bateson, D and Mak, O (2000) Has the dust finally settled on latent damages? *International Construction Law Review*, **17**, 675–88.

Burnett, J, Yik, F W H, Lee, W L, Powell, G, Chung, T M, Cheung, H and Tang, A (2004) *HK-BEAM 4/04: an environmental assessment for new buildings*. HK: HK-BEAM Society, available at http://www.hk-beam.org.hk/standards/beam.php.

Chan, A P C (2000) Evaluation of enhanced design and build system – a case study of a hospital project. *Construction Management and Economics*, **18**, 863–71.

Chan, E W H and Yu, A T W (2005) Contract strategy for design management in the design and build system. *International Journal of Project Management*, **23**, 630–9.

Chan, A P C, Ho, D C K and Tam, C M (2001) Evaluation criteria of public sector design and build projects in Hong Kong. *Journal of Construction Research*, **2**(2), 135–45.

Chan, A P C, Ho, D C K and Tam, C M (2002) Why design and build? Views from some major public clients in Hong Kong. Letter to the Editor. *Architectural Science Review*, **45**, 253–63.

Cheng, T, Wong, E and Soo, G (2004) *Construction law and practice in Hong Kong*. Hong Kong: Sweet & Maxwell Asia.

Chini, A R and Valdez, H E (2003) ISO 9000 and the US construction industry. *Journal of Management in Engineering*, **19**(2), 69–77.

Fox, S, Marsh, L and Cockerham, G (2002) Constructability rules: guidelines for successful application to bespoke buildings. *Construction Management and Economics*, **20**, 689–96.

Friedlander, M C (1998) Design/build solutions. *Journal of Management in Engineering*, **14**(6), 59–64.

Gaafar, H K and Perry, J G (1998) Limitation of design liability for contractors. *International Journal of Project Management*, **17**(5), 301–8.

Gann, D M, Salter, A J and Whyte, J K (2003) Design quality indicator as a tool for thinking. *Building Research and Information*, **31**(5), 318–33.

HKG (1999a) *General conditions of contract for design and build contracts, 1999 edition*. The Government of the Hong Kong Special Administration Region.

HKG (1999b) *General conditions of contract for building works, 1999 edition*. The Government of the Hong Kong Special Administration Region.

Hughes, W, Gray, C and Murdoch, J (1997) *Specialist trade contracting – a review*. Special publication 138. London: Construction Industry Research and Information Association.

Konchar, M and Sanvido, V (1998) Comparison of US project delivery systems. *Journal of Construction Engineering and Management*, **124**(6), 435–44.

Koskela, L, Huovila, P and Leinonen, J (2002) Design management in building construction: from theory to practice. *Journal of Construction Research*, **3**(1), 1–16.

Lam, E W M, Chan, A P C and Chan, D W M (2004) Development of the design–build procurement system in Hong Kong. *Architectural Science Review*, **47**, 387–97.

Latham, M (1994) *Constructing the team: final report of the government/industry review of procurement and contractual arrangements in the UK construction industry*. London: HMSO.

Love, P E D and Li, H (2000) Quantifying the causes and costs of rework in construction. *Construction Management and Economics*, **18**, 479–90.

Mantai, M (2006) Expanded role of the commissioning provider for LEED projects. *In*: *National Conference on Building Commissioning*, 19–21 April 2006, Portland, OR. Energy Conservation, Inc., available at http://www.peci.org/ncbc/proceedings/2006/title.htm.

Molenaar, K R, Songer, A D and Barash, M (1999) Public-sector design/build evolution and performance. *Journal of Management in Engineering*, **15**(2), 54–62.

Ndekugri, I and Turner, A (1994) Building procurement by design and build approach. *Journal of Construction Engineering and Management*, **120**(2), 243–56.

Ng, S T and Skitmore, R M (2002) Contractors' risks in design, novate and construct contracts. *International Journal of Project Management*, **20**, 119–26.

Parsloe, C J (1997) *Uptake of design responsibilities*, Report 78560. 2ed. London: The Building Services Research and Information Association.

Pietroforte, R and Miller, J B (2002) Procurement methods for US infrastructure: historical perspectives and recent trends. *Building Research and Information*, **30**(6), 425–34.

Scriven, J (1996) Design risk and liability under design and build contracts. *Construction Law Journal*, **12**, 226–39.

Songer, A D and Molenaar, K R (1996) Selecting design-build: public and private sector owner attitudes. *Journal of Management in Engineering*, **12**(6), 47–53.

Tan, R R and Lu, Y G (1995) On the quality of construction engineering design projects: criteria and impact factors. *International Journal of Quality & Reliability Management*, **12**(5), 18–37.

Way, M and Bordass, B (2005) Making feedback and post-occupancy evaluation routine 2: soft landings – involving design and building teams in improving performance. *Building Research & Information,* **33**(4), 353–60.

Yates, J K (1995) Use of design/build in E/C industry. *Journal of Management in Engineering,* **11**(6), 33–8.

Yik, F W H, Yee, K F, Sat, P S K and Chan, C (1998) A detailed energy audit for a commercial office building in Hong Kong. *Hong Kong Institution of Engineers Transactions*, **5**(3), 84–8.

Yik, F W H, Lee, W L, Burnett, J and Jones, P (1999) Chiller plant sizing by cooling load simulation as a means to avoid oversized plant. *Hong Kong Institution of Engineers Transactions*, **6**(2), 19–25.

Yik, F W H, Lai, J H K, Chan, K T and Yiu, E C Y (2006) Problems with specialist subcontracting in the construction industry. *Building Services Engineering Research and Technology,* **27**(3), 183–93.

FACILITIES ASSET MANAGEMENT: CHALLENGES AND OPPORTUNITIES

William W. Badger[1] and Michael J. Garvin[2]

[1]*Del E. Webb School of Construction, Arizona State University, PO Box 870287, Tempe, AZ 85287, USA*
[2]*Myers-Lawson School of Construction, Virginia Tech, 200 Patton Hall, Blacksburg, VA 24060, USA*

At the request of the Federal Facilities Council, the US National Research Council appointed a committee of experts to determine what organizational and individual competencies are necessary to 'help ensure effective federal facilities asset management (FAM) in the next fifteen years'. The collective wisdom of the committee is synthesized and presented as 'Ten Insights' about this evolving organizational function and professional discipline. The facilities asset management profession has gained new significance since the cost to adequately expand, modernize, repair and maintain enterprise assets and real property has begun to dominate budgets. Moreover, organizational leaders have recognized that the environments that facilities provide are mission enablers and require a significant investment of resources. These insights represent several significant outputs of the committee's work and are central to the development and growth of this discipline. The presentation is intended to provoke discussion and debate among the international community about the topic.

Keywords: asset management, facilities management, facilities performance, human resources management, real property management.

INTRODUCTION

The United States government owns more than 500 000 buildings, facilities and their associated infrastructure worldwide. These assets are valued in excess of $328 bn (FFC 2001). At least 30 individual federal agencies are involved with facilities acquisition and management, spending upwards of US$20 bn annually to acquire new facilities and renovate existing ones. Federal owners are increasingly recognizing the magnitude of the management challenge posed by such a portfolio. Moreover, they have begun to realize that facilities asset management is important to the future of the federal enterprise. At the bequest of the Federal Facilities Council, the US National Research Council appointed a committee of experts to determine what organizational and individual competencies are necessary to 'help ensure effective federal facilities asset management (FAM) in the next fifteen years'. The committee met on several occasions over the course of 1.5 years to study this topic and make its recommendations. The collective wisdom of the committee is synthesized and presented as 'Ten Insights' about this evolving organizational function and professional discipline. These insights represent the most significant outputs of the committee's work and are central to the development and growth of this discipline. The intent of this presentation is to provoke discussion and debate among the international community about the opportunities that facilities asset management will

[1] bill.badger@asu.edu

provide for construction management professionals and academics in the US. More than likely, the capital and effort expended in facilities asset management will soon match that expended in new construction.

TITLES AND NAMES

Over time the title and name for the ‘facilities asset manager’ and the profession of ‘facilities asset management’ has evolved. In reviewing the literature on the description and the development of facilities asset management, a variety of names and descriptions were uncovered. In some parts of the world, the word ‘facility’ instead of ‘facilities’ management is used. Atkin and Brooks’ (2004) definition truly captures the essentials of facilities management.

> Facilities management has traditionally been regarded as the poorer relation within the real estate, architecture, engineering, and construction professions. This is because it was seen in the old-fashioned sense of care taking, cleaning, repair, and maintenance. Nowadays, it covers real estate management, financial management, change management, human resources management, health and safety, and contract management, in addition to building and engineering services maintenance, domestic service and utility supplies. These last three responsibilities are the most viable. The others are subtler, although of no less importance. For facilities asset management to be effective, both the ‘hard’ issues, such as financial regulations, and the ‘soft’ issues, such as managing people have to be considered.

The International Facility Management Association (www.ifma.org) defines facility management as ‘a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology’. This definition clearly illustrates the holistic nature of the discipline and the interdependence of multiple factors in its success.

Elsewhere, the British Institute of Facilities Management (www.bifm.org.uk) promotes the development of facilities management as a critical, professional and strategic business discipline.

According to Lincoln (1968), Knight (1978), and Hilmes (1985), over the past 40 years the managers of installations and facilities for the US Army went through a number of name changes: post engineer, facility engineer, director of engineering and housing, and currently the director of public works. In the private US sector titles like plant engineer, building manager, physical plant manager, asset manager, and director of facilities emerged.

Throughout the committee’s investigation, much discussion regarding the titles to utilize was heard. The committee decided upon the moniker ‘facilities’, as is the case in the UK, versus ‘facility’, which is the current preference in the US. An additional consideration was the term ‘asset management’, which implies a focus upon asset and real property preservation to many whereas the term ‘facilities management’ connotes alignment of the property portfolio with the enterprise. The combination of the two into ‘facilities asset management’ suggests this discipline is charged with both requirements. Accordingly, the profession is titled ‘facilities asset management’ and the professional’s title is ‘facilities asset manager’.

SIGNIFICANCE

As the 21st century progresses, the facilities asset management function will gain unprecedented significance. Even today, the US federal government has already recognized the importance of this discipline for the ways that the federal government conducts its business. Various forces are driving the profession towards a different future:

- Within the US federal government, not the least of these is the *changing global landscape*. Real and perceived threats to national security as well as evolving global political and economic power balances have very tangible implications for federal facilities.
- As the baby boomer generation moves on, an *ageing workforce* presents the real possibility of workforce shortages in the near future. Moreover, the transition of this generation of workers could spell the loss of significant institutional memory and experience.
- The *workforce of the next generation* has very different expectations of the work environment and the nature of work. This generation is unquestionably the most ‘connected’ that the world has ever seen. Multi-tasking with various mediums of communication and information exchange is the norm. The workplace of the future must accommodate these types of workers and the style that accompanies them.
- *Rapid changes in information technology* are having remarkable impacts upon the ways that we live, work and interact. Indeed, links between people and organizations as well as connections to data, information and knowledge are changing society. The influence of IT upon facilities and facilities asset management is also quite pronounced. Today, IT is an inherent part of the work environment, where an enterprise’s information infrastructure is as important as its physical infrastructure. Moreover, IT is changing the physical infrastructure itself as well as the methods for its development and management.
- *Outsourcing* is no longer a novel trend since its presence as an organizational strategy now spans decades; however, the challenge for any enterprise, and particularly the facilities asset management function is to determine what activities or services are core to the enterprise’s mission and which ones are not.
- The *sustainability movement* has pushed society towards greater sensitivity of the environment. As more and more enterprises seek to minimize their environmental ‘footprints’, facilities are being correctly viewed as a tangible representation of an enterprise’s commitment to the environment.

These drivers of change have very tangible implications for FAM. First, future work environments are likely to be more diverse. One can imagine a situation where the workforce is remotely distributed and the organization’s space is only needed to facilitate face-to-face interaction periodically. Certainly, one can imagine many plausible future states. Regardless of what ultimately happens, the fundamental purpose of facilities asset management is to provide the enterprise with the appropriate environment or workplace for the conduct of its mission and business. Second, a world-class workplace will be necessary to attract a world-class workforce. The workplace is often an overlooked determinant in workforce recruitment and retention, and the workforce of tomorrow will have particular expectations for the work environment. Thus, the 'configuration' of the existing workplace will need to evolve. This will present a tremendous challenge as facilities asset managers search for ways to economically modify existing plant assets and expand the asset portfolio to meet the enterprise's new workplace needs. Third, 'smart' buildings will be more common in the future with legacy structures having been retrofitted with infrastructures that support both 'intelligent' and 'smart' work environments.

As budgetary pressures rise and as the coupling of the enterprise with the facility portfolio tightens, dollars allocated to facilities will increasingly be viewed as investments as opposed to costs. Return on investment (ROI) will become more and more a factor in property asset management, making life cycle planning more prevalent and visible.

Today, the facilities asset management function has grown from one that was focused upon operating and maintaining a single facility to one that is more strategic and has a broader perspective. To meet the challenges of tomorrow, facilities asset management must continue to evolve and it must do so quickly. Facilities asset managers must step beyond their traditional comfort zones of project-level management and field-level decision making towards programme management and executive-level decision making.

Tomorrow, facilities will have become very important elements of the federal mission and objectives. They will be strategic assets to the organization, assets which have the capacity to dramatically shape federal government's services, workforce, finances and environmental performance. But this potential value does not come without risks. Failure to improve and modernize facilities can degrade government performance as easily as success can empower it. Antiquated and obsolete facilities constrain business processes, hinder workforce productivity and recruitment, and cost the organization too much economically and environmentally. Indeed, when facilities are considered strategic assets, they occupy a different place in the government's value and risk equation. Any resource that has the potential to influence effective and accountable government must receive appropriate organizational attention.

UNIQUENESS

The roles and responsibilities of the facilities asset manager are unique among managers in the life cycle management system. The horizontal nature of the organization increases the challenge of efficient information flow. It creates a condition where a wider range of core competencies and professional development is needed. The 'facilities asset managers' must educate and train the facilities asset management workforce.

The facilities asset manager is a 'connected integrator' of multiple functions. The roles and responsibilities for this class of manager are unique among managers in the capital life cycle project system. This manager must be connected, empowered to integrate, and able to influence multiple functional areas. The graph in Figure 1 below shows the involvements of the stakeholders (owners, clients, designers, constructors and facilities asset managers) throughout the life cycle.

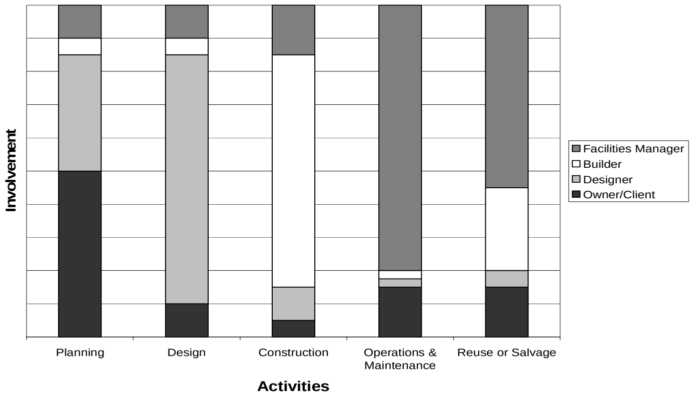


Figure 1: FM role in the project life cycle

Of all the various parties involved in a project's life cycle, the facilities asset manager is the only one involved throughout the life cycle serving as the dominant player throughout the operations and maintenance phase, which constitutes over 90% of the life cycle work.

INTERFACE WITH THE ENTERPRISE

Enterprises must empower this leader to integrate and to influence multiple functional areas. The graph in Figure 1 illustrates the 'relative' involvement of the stakeholders (owners/clients, designers, builders and facilities asset managers) throughout the life cycle of a typical facility. Granted, the amount of involvement can differ for particular circumstances, but the point is that facilities asset managers have significant roles from the start and their responsibilities only increase. Moreover, the facilities asset manager is the dominant player during the operations and maintenance phase, which can constitute the vast majority of the facility's service life – particularly for institutional-type owners.

Clearly, the leader of the facilities asset management function has an unparalleled perspective of an enterprise's real assets. To leverage the potential of these assets to enhance productivity, improve employee health and safety, increase the bottom line and better the environment, an enterprise must empower the facilities asset management function with appropriate resources and authority. A 'chief facility officer' who has the same stature as a chief operating officer or a chief financial officer is necessary to guarantee proper visibility of these resources. In fact, facilities cannot become an organizational multiplier if they are not part of top level discussions about strategic issues such as long-range planning and resource allocation. To become more than an afterthought, the senior facility manager must be part of the organization's executive team.

LEADERSHIP

Facilities asset managers will need increased leadership skill sets to be able to lead the workforce instead of being just a practising manager without necessary leadership skills. Facilities asset management organizations must implement a leadership transformation model to change to a more focused leadership organization.

Core competencies should be structured to ensure that leader development efforts are focused on the attainment of high levels of individual and organizational performance. They can also be structured to be enduring even as resources diminish, demands increase, and priorities and strategies shift. Competencies provide a basis and a common language for discussing educational publications, doctrinal manuals, assessment and feedback tools, and ways to access distance and distributed learning programmes for self-development and lifelong learning. Figure 2 shows the balance between skills during career progression.

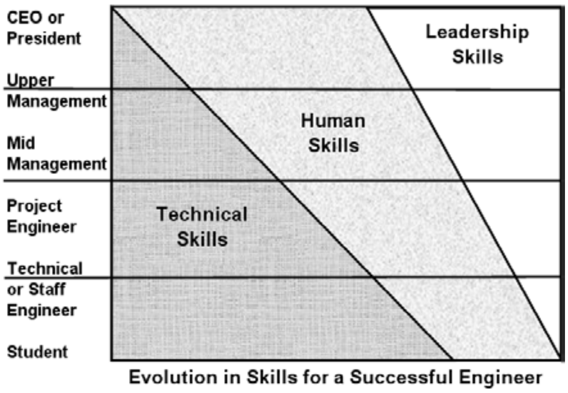


Figure 2: Leadership developments for engineering managers (Farr *et al.* 1997)

Leadership transformational model

According to Badger and Garvin (2007) executives in architecture, engineering and construction (AEC) initially receive their education and degrees in areas of study with a technical focus. These graduates are then required to learn new skills in FAM if they are to progress within their respective career fields.

In the Badger *et al.* (2007) papers, researchers are using a framework for the leadership transformational programme that could guide companies or organizations to a leadership model and promote the education and training required to enhance the organization's leadership skills. A modification of the steps found in the US Marine Corps (2006) training model was considered the most useful. The resulting research would allow a company to introduce new knowledge, implement this knowledge, and change the culture to address the seven leadership steps described below:

1. Leading and knowing self.
2. Preparing to lead by gaining leadership skill awareness.
3. Lead the workforce by implementing leadership skills.
4. Lead subordinate leaders while practising leadership.
5. Develop subordinate leaders' teams.
6. Develop leadership climate by empowering and developing.
7. Lead changes of the processes by implementing best value for the organization.

NEW CORE COMPETENCIES

Figure 3 illustrates a new framework for the facilities asset management function. This framework is a bit of a departure from the traditional view of this function as one that only plans, acquires and tends to constructed facilities. The leaders of this function must adopt the governing mindset of a smart owner. The term 'smart owner' is used in the commercial design, engineering, and construction industry to designate a business entity that has the skill base – usually a staff with the professional qualifications and authority – necessary to plan, guide and evaluate the facility acquisition and management process. A smart owner focuses on the relationship of a specific facility to the successful accomplishment of an organization's business or overall mission (FFC 2000). The governing behaviour of the FAM function is focused upon strategic decision making that emphasizes a life cycle management approach and continuous improvement. Core competencies for facilities asset management teams have evolved and require *integration* (of facilities services), *alignment* (with the agency mission), and ongoing *innovation* (to address future needs and opportunities). Organizational capabilities that support these core competencies are *business management*, *professional* (technical) *competence*, and *behavioural skills*. The FAM function also requires people with a diverse array of individual skills who can truly leverage enterprise knowledge to enable it to achieve its objectives.

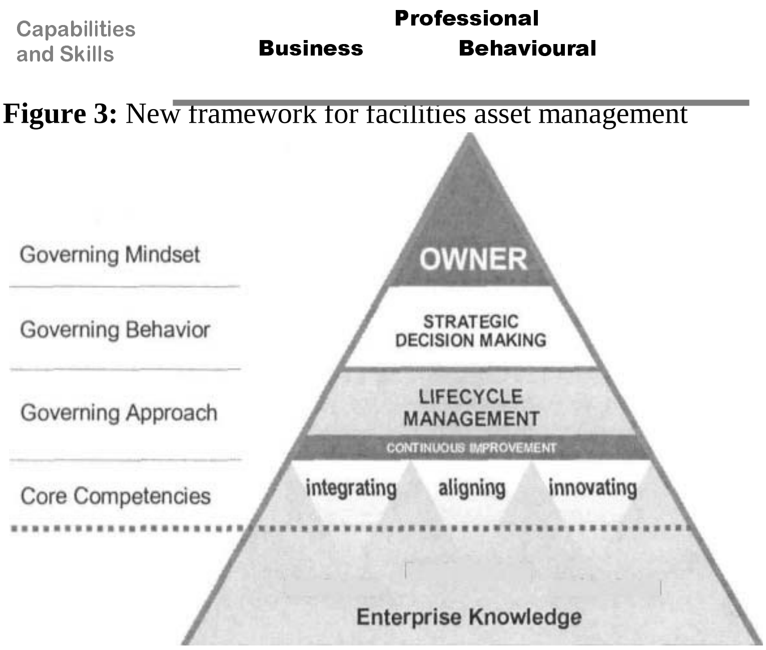


Figure 3: New framework for facilities asset management

Governing mindset – owner

Every professional in facilities asset management must take ownership of the organization's facilities. This is more than a cliché. Each professional must treat each workspace, each meeting room and each division's headquarters as if it were his/her own. This perspective allows facilities to respond to the agency's needs appropriately. To appreciate how important an ownership mentality is, compare the basic behaviour of the home renter versus the home owner. Moreover, the owner envisions the space as it ‘might be’.

Key behaviour – strategic decision making

Facility operational decisions and the associated management of the respective facility assets directly impact on enterprise service as well as financial and environmental performance. Therefore, enterprise or corporate leaders must understand and appreciate the impact of facilities and facilities asset managers on the enterprise. Hence, one of the most important responsibilities of the facilities asset management function is to ensure the appropriate information is evaluated for decision making. Within the facilities management community, many refer to this notion as ‘informing the client function’. Essentially, this is a strategic decision-making process that leads to configuring or adapting the facilities portfolio to suit the organization and its mission. To achieve this, senior leaders must: (1) understand how facilities impact on the mission; (2) establish appropriate policies for facility acquisition, management and disposal; (3) allocate adequate resources to support facility policies and management; and (4) evaluate facilities services systematically to determine the ‘fitness’ of the facilities portfolio.

Approach – life cycle management

Facilities asset managers of the future must take into consideration the entire life cycle of buildings and facilities portfolios. Since 85–90% of a building’s life cycle costs are post-construction, taking a total asset management perspective and understanding the concepts of total cost of ownership for facilities are vital. Proper stewardship of facilities requires an understanding of the importance of the interrelationships among these costs, thus enabling the development of cost-effective maintenance management plans.

Total asset management and total cost of ownership approaches consider the overall life cycle of facilities, from planning/design/construction through operations and maintenance to capital asset management and facility renewal or disposal. The importance of implementing a facility asset management approach that integrates facility operation and maintenance considerations with facility capital investments cannot be overstated.

Core competencies – integration, alignment, innovation

C*ore competencies* are knowledge, skills and abilities identified within a specific organization to enable successful performance of planned objectives. Core competencies need to be re-examined on a regular basis, often as part of the overall planning and budgeting process, to ensure they align with the organization’s needs. If the core competencies and the organization’s mission are unaligned, inefficiencies resulting from this mismatch (at the individual, team and/or organizational level) may exist, potentially leading to failure in meeting planned objectives.

Many professions are typically involved in the development and management of real assets. These include real estate, architecture, engineering, construction and facilities management. Of these, facilities asset managers are the only professionals fully engaged on a day-to-day basis, throughout the asset life cycle.

Integrating the various stages, activities, and players; *aligning* the diverse teams and tasks to one mission; and *innovating* across traditional functional lines to enable strategic decision making and achievement of objectives are the core competencies that the facilities asset management function must demonstrate to add value and contribute to enterprise/mission success. These competencies represent the future of this discipline. Indeed, the more traditional skills (related to planning, acquisition, management and disposal) are necessary; however, if both physical and virtual spaces are to act as one to facilitate organizational success, then a new skill set is vital for the leaders of the FAM function.

FUTURE WORKFORCE

It is essential that the facilities asset management organization has the ability to attract and recruit high quality employees to achieve world-class status. The marketing and selling of the new facilities asset management career field will be required and the education and training of the new workforce is needed. The development of the workforce will need continuous attention and investment.

A professional with a honed set of leadership and management skills will continue to progress whereas one who is lacking such skills will likely reach a point of career stagnation. One effective approach to ensure access to a pool of FAM talent is for universities and colleges to provide education, certifications and degrees in this field. In some corners of academia, scrutiny and serious consideration are being given to this new field of endeavour in higher education. However, the pipeline for new degrees in facilities asset management likely will not be producing such talent in the near future. This will require facilities asset management organizations to continuously educate and train the existing workforce.

Figure 4 illustrates the typical profile of academic disciplines for many universities and colleges in the US. It highlights the fact that few departments, schools or colleges are currently addressing the FAM field of university educated professionals. This lack of university graduates in the FAM field necessitates recruiting entry level BS graduates from other disciplines. This also requires better marketing of career opportunities to attract recruits and the need for increased facilities asset management image building.

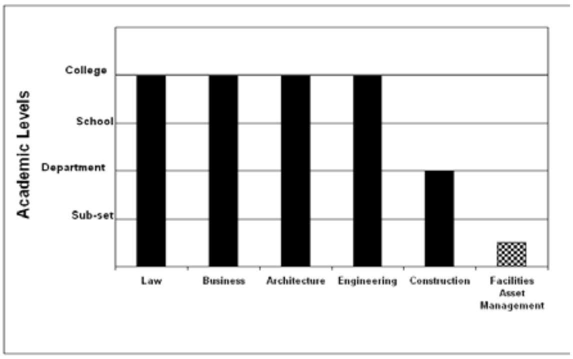


Figure 4: Typical profile of academic disciplines

A comprehensive workforce development programme should include both new and current employees. The establishment of such a programme will require the creation and adoption of a recognized education philosophy, and a core set of values that underlie all of the respective development components. It is vital that support be sustained with annual budgets, focusing on the development of the agency's core competencies.

RESEARCH

Research (knowledge development) is the cutting edge area of any growing field or discipline. The knowledge developed from research activities serves not only the immediate professional community but also those who are served by that community. For facilities asset management to become a true profession, knowledge development must play a significant and extensive role, with the results implemented in an effective manner. The knowledge development process will provide a continuous improvement environment for corporations, professional organizations and individual professionals themselves. Formal programmes ensuring such an environment need to be established.

The most immediate, applicable form of knowledge development is that which is internally generated. It is likely to have the most immediate impact. If an enterprise does not have adequate internal resources to conduct extensive research, engaging an outside source of expertise can serve this purpose. Such studies may come from academia, professional societies or from private consultants. Outside organizational utilization in conducting research, in addition to providing personnel and expertise, can also provide the 'independent voice' needed for credibility. Most 'breakthrough' contributions come from such sources because of the 'risky' nature of such endeavours. Involvement of enterprise human resources is still desirable and needed to ensure proper guidance of the research efforts. This involvement will also provide added benefit for the individual's experiential growth and will increase the potential for implementation of study results. Involvement usually enhances buy-in, promotes implementation and facilitates cultural change.

Unfortunately, US universities intending to develop and grow facilities asset management research areas and to add new areas of discovery and investigation are starting with little recognition or support. A monumental task awaits the US institution or the individual desiring to embark upon a path of discovery in the facilities asset management field. Despite the fact that research and educational outcomes have the potential to change the business practices and technologies of facilities owners worldwide, who collectively hold physical asset portfolios valued in trillions of dollars, the critical mass needed to launch FAM research is missing.

INVESTMENT IN EDUCATION AND TRAINING

One step in building a comprehensive workforce development programme is to identify educational needs, available training sources, and potential alliance partners from professional societies and organizations. Another step is to create innovation, new knowledge (research), and new product knowledge transfer mechanism to import ideas, technologies and knowledge into facilities asset management organizations. This model will capitalize on the capabilities of professional societies with an extensive knowledge and expertise base in facilities asset management. To accomplish the above educational, training and research programmes will require annual funding. According to Rose and Nicholl (2002) implementation of an effective development program will require both personnel and financial resources, in the range of 2–5% of an agency's personnel budget. Effective education and training that yields the right level of professional development have become recognized as not only valuable, but also necessary in maintaining an effective executive work force. Some examples of budget allocations targeted for professional development include:

- Motorola University, budgeting 3.6% of its payroll on training, some $120m p.a.;

- Saturn Corp – with its emphasis on debating shared values, cooperative decision making, teamwork, setting the expectation that every employee will undertake 100 hours a year of formal education;
- General Electric, placing 13 000 employees on a two-day thinking skills/problem-solving course;
- Fel Pro, reimbursing tuition costs for employees and paying bonuses to people who earn degrees;
- The Arup Partnership, allowing 10% of all employee time to be devoted to continuing education.

THE FUTURE

The forces of change are already at work. In particular, the demands to do more with less will not wane and the push towards more environmentally sustainable practices will prompt more frequent use of a remote workforce as enterprises attempt to minimize costs and conserve energy. Meanwhile, advances in IT will make the utilization of a remote workforce more feasible and effective. People will be more mobile and even more connected. Information technology will help to redefine the conduct, place and products of work. Current technologies already make it possible to generate documents that are designed for paperless reading, to obtain music without visiting a record store, and to plan and execute work without the benefit of office space. These trends will continue as the ‘digital’ world becomes more and more prevalent. The workforce and workplace of the future will not resemble that of today.

As this happens, the facilities asset management function and the facilities asset manager will evolve and become better recognized and established. This ‘evolution’ will occur regardless of whether an enterprise recognizes it or not. Those that do will have a competitive edge since they will realize that this discipline will become a core organizational function that: (1) provides an enterprise with the work environment necessary for its mission by integrating people, place, processes and technology; and (2) maximizes both the financial and environmental value of facilities throughout their life cycles.

CONCLUSION

This paper has discussed a number of challenges about the changing environment of the facilities asset management profession and the authors have identified some key (10) issues that need attention and innovative solutions:

1. *The title and name*: Over time the title and name for the ‘facilities asset manager’ and the profession of ‘facilities asset management’ has evolved and the recent NRC study recommends the above title and name.
2. *The significance*: The facilities asset management profession has gained new importance because of increasing budgetary pressures. The cost to adequately expand, modernize, repair and maintain an enterprise’s assets and real property has begun to dominate budgets. Moreover, organizational leaders have recognized that properly utilized and well-maintained facilities are mission enablers and require significant investment of resources.
3. *The uniqueness*: The roles and responsibilities of the facilities asset manager are unique among managers in the life cycle management system. The horizontal

nature of the organization increases the challenge of efficient information flow. It creates a condition where a wider range of core competencies and professional development is needed. The facilities asset managers must educate and train the facilities asset management workforce.

4. *The interface*: The recognition of the facilities asset manager's position as a senior executive is paramount for agencies/organizations/companies to accomplish their mission in an efficient and economical fashion. The facilities asset manager should be an active member of the agency's executive decision making leadership group.
5. *Leadership*: Facilities asset managers need increased leadership skill sets to be able to lead the workforce instead of being just a practising manager without the new leadership skills. The facilities asset management organizations need to implement a new leadership transformation model to change to a leadership organization.
6. *New core competencies*: The new facilities asset management function must adopt: (1) a smart owner's mindset; (2) a governing behaviour of strategic decision making; (3) a governing approach of life cycle management; (4) core competencies of integrating, aligning and innovating; and (5) key capabilities and skills in business, behavioural, enterprise knowledge and professionalism.
7. *New workforce*: It is essential that the facilities asset management organization has the ability to attract and recruit high quality employees to achieve world-class status. Marketing and selling of the new facilities asset management career field are required and the education and training of the new workforce is needed. Development of the workforce will need continuous attention and investment.
8. *Research*: Little university and private research information exists in the field of facilities asset management and even less research funding is being introduced or implemented. Facilities asset managers need to invest in developing new research in facilities asset management processes to improve overall performances.
9. *The investment*: Facilities asset management organizations need to invest 2% of their salary budgets on education and training of their workforce and research in process innovations.
10. *The future*: The facilities asset manager career field and the facilities asset management profession will become recognized and established as each matures and investments are made.

REFERENCES

Atkins, B and Brooks, A (2005) *Total facilities management.* Oxford: Blackwell.

Badger, W W and Garvin, M J (2007) Facilities asset management: a new career field for construction management graduates. Paper presented at the Associated Schools of Construction 43rd Annual International Conference, 12–14 April 2007, Flagstaff, AZ.

Badger, W and Smith, J (2006) Great leadership skills and traits. *In*: *Proceedings 2nd Specialty Conference on Leadership and Management in Construction,* 4–6 May 2006, Grand Bahamas Island, Bahamas, 141–54.

Badger, W W, Bopp, P H and Wiezel, A (2007) Leadership research: enhanced leadership skills improves performance. Paper presented at the ASCE 2007 Construction Research Congress, 6–8 May 2007, Grand Bahamas Island, Bahamas.

Farr, J V, Walesh, S G and Forsythe, G B (1997) Leadership development for engineering managers. *Journal of Management in Engineering*, **13**(4), 38–41.

FFC (Federal Facilities Council) (2001) *Sustainable federal facilities: a guide to integrating value engineering, life-cycle costing, and sustainable development*. Washington, DC: National Academy Press.

Hilmes (1985) *The Green Ribbon Report on US Army Corps of Engineers' support to army installation commanders*.

Lincoln (1968) *Total management of real property maintenance activities: RPMA.*

Knight (1978) *Study to improve real property operations and maintenance in the army*.

NRC (2000) *Outsourcing management functions for the acquisition of federal facilities*. Washington, DC: National Academy Press.

Rose and Nicholl (1998) *Accelerated learning for the 21st century. the six-step plan to unlock your MASTER mind.*

US Marine Corps (2006) *Non-commissioned officers (NCO) course*.

THE BEST CRITERIA FOR THE SELECTION OF CONTRACTORS IN THE DUTCH CONSTRUCTION INDUSTRY!

Ruben Favié[1], Ger Mass and Gaby Abdalla

School of Construction Management and Engineering, Technische Universiteit Eindhoven, Den Dolech 2 Vertigo 08.09 Eindhoven Noord Brabant 5600 MB, The Netherlands

Selecting contractors in the Netherlands is often done by the criterion of lowest price. This leads to a lack of innovation and a loss of quality in the construction industry. From the field of purchasing and procurement, we learn that there are several theories and processes for finding the best contractor for the execution of a work. One of the steps in those processes is the assessment of the contractors on the basis of specific criteria. Which criteria have to be used depends on the wishes of the client. But what are, in general, the best criteria to use? Assessment is on the basis of which criterion or combination of criteria really says something about the quality of the cooperation and the final product. In this research, a comparison is made between the criteria that were found in literature with the criteria that were found during a study on the Dutch construction industry. The aim of this research is to find the best criteria for the selection of contractors in the Dutch construction industry.

Keywords: client, criteria, government, innovation, procurement, tendering.

INTRODUCTION

The Dutch building industry is changing. Like in other countries, there are big programmes initiated by the government to improve the industry as a whole. One of the most important aspects of these programmes is the way that clients select and weigh up their partners. The partner, in this case is the contractor.

Building projects are getting more complex. Because of that, the contractors that build these projects have to meet specific demands. Nowadays, the most important criterion for tendering in the Dutch construction industry is price. This means that the contractor that offers the lowest price gets the work. In the Enquete Bouwnijverheid, performed by the Dutch Government in 2003, the disadvantages of this way of tendering are mentioned (Parlementaire Enquetecommissie Bouwnijverheid 2003). The research points out that the criterion of lowest price does not stimulate and augment the quality of the work and innovation in the building industry.

Also, because of the lowest price tendering, all contractors have to do exactly the same thing. Because of this, there are hardly any contractors with a particular expertise. This is very bad for innovation in the industry. This way of tendering also leads to highly divided responsibilities and in a lot of cases bad relationships between

[1] r.favie@bwk.tue.nl

contractor and client. These bad relationships are a result of the fact that contractors try to come up with the lowest possible price. When they have the lowest price in the tender, they are allowed to build the project. During the project, the contractor tries to earn as much extra money as possible. When, for example, the client wants to make a little change in the design, the contractor will ask a lot of money for that. Most of the time he will ask for more money than he really needs to fulfil that job. This will lead to distrust, unpleasant situations and negative energy.

To conclude we can say that lowest price tendering might not be the best way to select a contractor. It would be better to select a contractor and build in a team where the participants can trust each other, and work for the same goal. That will lead to better working situations and more value for every partner in the team.

The question is then: which criteria have to be used to select a contractor in order to reach your aim and create the best value for your organization? In this paper, an overview of existing literature in the field of criteria for supplier selection is compared with a study that was done on the Dutch construction industry. The findings of this research result in recommendations for Dutch clients: which are the best criteria to use in the contractor selection process?

THE CONTRACTOR SELECTION

One of the most important steps in every production process is the selection of a supplier. In the construction industry, very difficult, unique products have to be developed. In the construction industry, one of the suppliers is the contractor. He is responsible for the execution of the work.

Although there are a lot of differences between the construction industry and other industries, the principle of selecting suppliers is the same: a client buys a product from a supplier. The whole process of supplier selection has been discussed in literature for several years. Van Weele has developed a purchasing model that includes the following steps:

1. Determining specification
2. Selecting supplier
3. Contracting
4. Ordering
5. Expediting and evaluation
6. Follow-up and evaluation

Another model for contractor selection is developed by Momme and Hvolby (2002) and is called the outsourcing framework. It contains the following steps:

1. Competence analysis
2. Assessment and approval
3. Contract negotiation
4. Project execution and transfer
5. Managing relationship
6. Contract termination

In each second step of these processes respectively ‘Selecting supplier’ and ‘Assessment and approval’, the determination of criteria for the selection is a very important issue. The problem here is that neither Van Weele nor Momme give the best criteria. In the next paragraph, an overview is given of the literature that handles the right criteria for supplier selection.

THE CRITERIA

In the past 40 years, a lot of research has been done on the issue of criteria for supplier selection. One of the first authors to write on this topic was Dickson (1966). He indicated 23 supplier selection criteria. According to Dickson, cost, quality and delivery performance are the most important criteria. More recent research, done by Choy *et al*. (2003), identifies 18 criteria that were divided into seven groups. Jain *et al*. (2007) formulated groups with six main categories:

1. Cost
2. Quality
3. Cycle time
4. Service
5. Relationship
6. Organizational profile

In this research these groups and the criteria that are in these groups will be used.

METHODOLOGY

Step 1: expert panel
The first step in this research was a workshop in which 15 experts from the construction industry were asked to share their most important criteria for selecting a supplier in construction. The workshop was held as part of a congress at the University of Eindhoven on 2 June 2005. The 15 experts were asked to write down their most important criteria for the selection of a supplier. Doing this, a list of criteria was collected that was completed and refined by a monologue by each of the experts in which the expert was able to explain what his most important values in the process of selecting a supplier were. This collection of 51 criteria is grouped conformable to the categories of Jain *et al*. (2007).

Step 2: survey
The list of criteria that was collected by the expert panel of step 1 was the input for a big survey that was held among over 100 respondents from the Dutch construction industry. This survey was held during a congress at the University of Eindhoven on 8 June 2006. In this survey, the respondents, all professionals from the building industry and students, were asked to rank the criteria on a scale from 1 to 4 (not important – reasonably important – important – highly important). There were 111 respondents, of which 25 were students. Because of their lack of experience in the industry, their responses were not used. So, at the end, the responses of 86 respondents were used.

The survey included 12 criteria. These criteria were filtered out of the list that was the result of step 1 by comparing the supplier selection criteria of Jain *et al*. with the list of the expert panel.

RESULTS

Step 1: expert panel

The criteria that were collected during the workshop with the expert panel can be seen in Table 1. The criteria are compared to the criteria that Jain *et al*. determined. From this comparison, 12 criteria are chosen for the next step in the research, the survey. These 12 criteria are a direct match between the criteria of Jain *et al*. and the criteria from the expert panel. For the criterion of 'Cycle time' that Jain *et al.* collected, no match was found, therefore that criterion was not taken into account for the survey. The criterion of financial stability that was found by Jain has not been named by the expert panel, but because of its importance in the process of selection, that criterion was added to the survey.

Table 1: Comparison of the criteria from Jain and the criteria from the expert panel

Jain *et al.* (2007)	**Expert panel grouped by Jain**
Cost	Cost
Price	*Price/quality ratio*
Logistics costs (transportation, inventory, administration, Customs, risk and damage, handling and packing)	
Operating costs	
After sales service costs	
Relationship	Relationship
Visitation to supplier facilities	Accessibility
Trust and partnership	*Trust*
Compatibility across levels and functions of buyer and supplier firms	*Match*
Business references	Respect
Supplier's customer base	Personal cooperation
Financial stability	
Strategic contribution	Fun
Reliability	*Reliability*
Expectation of continuity	*Reciprocity*
Dependability	*We are not able to do it on our own*
Need identification ability	Good feeling
Cultural similarity	Going for the same goal
Negotiable ability	No nonsense approach
Amount of past business	Enthusiasm
Ability to maintain commercial relations	Culture
Supplier availability	Damage risk
Industrial relations	Dependence
Risks	Returns
	Openness
	Partner must be able to complement me
	Partner has to do one's best
	The project and the objectives must fit the company's values
	Added value: win-win

	Synergy
	Open communication
	Ethics
	Cooperation on the basis of equivalence
	Not being corrupt
	Long-term relationships
	Mutual dependence
	Loyalty
	Mutual interests
	Communication
	No frustrations
	Expectancy
Quality	Quality
Quality performance (e.g. ISO 9000 accreditation)	*Quality*
Marketability	good processes
Durability	
Ergonomic qualities	
Flexibility of operation	*No concerns/worries*
Simplicity of operation	
Reliability	
Organization	Organization
Performance history	*Experience*
Future technology (e.g. investment in R&D)	Expertise
Management capability	Specialism
Geographical location	Partner has to come up with intelligent solutions
Environment performance (e.g. ISO 14001 certification)	Improving processes
Human resource practices	Juridical
Supplier management	Bring together technique and politics
Financial management systems	Complexity
Production facilities and capacity	
Position in the industry and reputation	*Image*
Current technology (product, process)	
Physical size/growth	
Technological capabilities	Cooperation: the content
Innovativeness	Innovation
EDI capability	
Service	Service
Reaction to demand	*Cooperation: organizational*
Ability to modify product	Appointments
Supply variety	
Technical support	
After sales services (e.g. warranties and claims policies)	
Flexibility (payment, freight, price reduction, order frequency & amount)	
Delivery frequency	
Cycle time	Cycle time
Speed to market	

Delivery lead time
Development speed
On time delivery
Fill rate

Step 2: survey

The comparison of step 1 (Table1) results in 12 criteria that were the subject of a survey. In Table 2, these criteria are shown. In the survey, 86 professionals from the Dutch construction industry could rank these criteria on a scale of 1 to 4. The results of this survey can be seen in Table 3.

Table 2: The criteria for survey 1

- Price
- Quality
- Good cooperation
- Creditworthiness
- No nonsense
- A good match
- A partner is able to do something that we can not do
- Trust
- Experience
- Reciprocity
- Image of a partner
- Reliability

The results in Table 3 give an insight into the way the Dutch professionals think about these criteria. The range of the answers is very wide. Because of that, it was only possible to determine the mean of all the rankings.

Table 3: The results of survey 1

	Modus		**Mean**			
Criterion	**All participants**	**All participants (111)**	**Contractors (22)**	**Consultants (41)**	**Real estate developers (11)**	**Public clients (12)**
Price	Important	2,92	2,86	2,95	3,00	3,00
Quality	Highly important	3,74	3,68	3,76	3,82	3,75
a good cooperation	Important	3,17	3,09	3,15	3,09	3,00
Credit-worthiness	Important	2,85	2,95	3,05	3,09	3,00
No nonsense	Important	2,74	2,68	2,66	2,45	2,5
A good match	Important	3,36	3,32	3,39	3,36	3,33
A partner is able to do something that we can not do	Important	3,17	3,23	3,17	3,36	3,42
Trust	Highly important	3,8	3,86	3,83	4	4,00
Experience (references)	Reasonably important	2,4	2,23	2,27	2,55	2,50
Reciprocity	Important	2,74	2,86	2,78	2,73	2,75
Image of a partner	Reasonably important	2,49	2,41	2,37	2,64	2,58

Reliability	Highly important	3,8	3,82	3,85	3,91	3,83

DISCUSSION

In the field of procurement and purchasing, a lot of models are being developed that can help businesses with the selection of suppliers. In most of those models, the criteria for selection play an important role. In this study, a comparison is made of some existing literature from the field of supplier selection with research that has been done in the Dutch construction industry. The criteria that were found in literature for selecting a supplier have been compared with the criteria that were found in Dutch construction for selecting a contractor. From this comparison it can be said that there are a lot of similarities. The ranking of the criteria, however, was very difficult. Probably, the reason for that was the fact that the 86 respondents who ranked the criteria were not working in the same projects and in the same companies. For every new project, the client has to rank the criteria again, because every project has its own characteristics. Because of the similarities between the existing literature on the criteria for selecting suppliers, it can be said these criteria are very useful for selecting contractors in the Netherlands.

REFERENCES

Choy, K L, Lee, W B and Lo, V (2003) Design of a case based intelligent supplier relationship management system – the integration of supplier rating system and product coding system. *Expert Systems with Applications*, **25**, 87–100.

Dickson, G W (1966) An analysis of vendor selection systems and decisions. *Journal of Purchasing*, **2**(1), 5–17.

Jain, V, Wadhwa, S and Desmukh, S G (2007) Supplier selection using fuzzy association rules mining approach. *International Journal of Production Research*, **45**(6), 1323–53.

Momme, J and Hvolby, H H (2002) An outsourcing framework: action research in the heavy industry sector. *European Journal of Purchasing & Supply Management*, **8**, 185–96.

Parlementaire Enquêtecommissie Bouwnijverheid (2003) Rapport Parlementaire Enquête Bouwnijverheid.

Saaty, T L (2001) *The fundamentals of decision making and priority theory with the analytic hierarchy process*.

Van Weele, A J (2005) *Purchasing and supply chain management: analysis, strategy, planning and practice*. London: Thomson.

NON-CONFORMITIES IN FLEXIBLE PAVEMENTS: A THEORETICAL AND EXPERIMENTAL STUDY ON PAY ADJUSTMENT

Filippo G Pratico[1]

University Mediterranea of Reggio Calabria, Via Graziella Feo di Vito, Reggio Calabria, 89100, Italy

Highway pavements are multi-layered and complex systems. Inspection, sampling and testing are necessary to determine the degree of compliance of the as-constructed pavement with the as-designed pavement (i.e. contract requirements). This phase is called acceptance and a pay adjustment system is finally required in order to assign pay factors and contractors' liabilities. In particular, conditions may occur in which the friction course is a premium material and performs very well, while in the binder course many defects are detected and thus the milling of both the binder and the surface course is required. In such cases, a method to identify liability, estimate pay adjustment and contribute to dispute resolution is needed in order to divide responsibilities and penalties among different subjects and layers. Such a method is proposed. A model, based on life cycle cost analysis (LCCA) of the flexible pavement has been formalized and an experimental application (case history) is presented. Results demonstrate that acceptance criteria based on pavement experimental investigation and LCCA can give a reliable solution for pay adjustment quantification and subdivision.

Keywords: quality assurance, cost, roads, contract administration, life cycle.

OBJECTIVES AND SCOPE

The main objective of this paper is to propose a methodology for solving the issues of detection, analysis and acceptance of a multi-layered pavement in which defects in inside layers are detected. Flexible pavements are considered. In order to pursue the above-mentioned objective, construction, economical and juridical issues have been analysed and discussed; given that premise, an acceptance criterion has been formalized and applied to a real case history.

METHODOLOGY: PART I – ANALYSIS OF FAILURE, CONSTRUCTION ISSUES

In this section, construction issues pertaining nonconformities of inside layers of a multilayered road pavement are analysed; the structure of the problem in terms of acceptance criteria is investigated as key factor for dispute resolution. Premature non-conformities are usually detected "*de visu*" as surface distress.

Surface distress is "Any indication of poor or unfavourable pavement performance or signs of impending failure; any unsatisfactory performance of a pavement short of failure" (Highway Research Board 1970). Surface distress modes can be broadly classified into the following three groups: (a) *fracture* (cracking resulting from

[1] filippo.pratico@unirc.it

excessive loading, fatigue, thermal changes, moisture damage, slippage, etc.); (b) *distortion (*rutting, corrugation and shoving, which can result from such things as excessive loading, creep, densification, consolidation, swelling, or frost action); and (c) *disintegration* (stripping, ravelling, which can result from such things as loss of bonding, chemical reactivity, traffic abrasion, aggregate degradation, poor consolidation/compaction or binder aging, etc.). Thus, in general, surface distress can be related to the structural integrity of pavement.

Surface cracking can result from the overall performance of the multilayer system (pavement); the balance among the mechanical properties of the different layers rules (under given load conditions) where and when cracks will appear and how they will propagate thorough the multi-layered pavement system.

So there is the possibility to detect surface distress substantially related to the failure of inside layers; a class of typical premature, impulsive degradation phenomena originates from the breakage of the link between asphalt binder and aggregates. Separation or removal of asphalt binder from aggregate surface due primarily to the action of moisture and/or moisture vapour is generally termed stripping.

The following factors can be useful in detecting and analysing phenomena, acceptance criteria and liabilities (Kandhal and Richards 2001; Schaus and Tighe 2007; Long and Ioannides 2007):

1. Physio-chemical incompatibility of the asphalt system is a key factor. Aggregate prone to stripping (e.g. siliceous aggregates), particular asphalt binders and traffic can be important factors.
2. Interaction between different hot mix asphalt (HMA) courses (including Open – Graded Friction Courses, OGFC, or porous european mixes (PME)) can be relevant. As a mater of fact, according to some authors, there are numerous examples of stripping that occurred in dense graded HMA followed by an OGFC overlay.
3. Stripping phenomena often occur within 6–18 months from the construction, and either a moisture surplus area or sufficient diurnal temperature range is necessary to start the “heat pump” and get moisture movement within the road (Emery 2006).
4. Extensive milling can be needed.
5. Stripping is influenced from aggregate selection, asphalt binder selection, pavement design, mixture design, construction, drainage and additives (Lavin 2002).
6. Besides high air void content (Turochy and Parker 2007), three essential factors seem to promote stripping: the presence of water, high stress, high temperature range. In particular, dusty or dirty aggregates can affect stripping susceptibility.
7. The following main theories on stripping mechanism can be listed: detachment (i.e. microscopic separation of the asphalt film from the aggregate), displacement (i.e. breaking of the film), emulsification (in presence of water), film rupture (ruptured asphalt films at sharp aggregate surfaces or due to dust), hydraulic scouring (scouring of the asphalt film through the action of traffic and water), pH instability, pore pressure (air voids becoming saturated with

water), etc.; each of them can greatly contribute to understand and attribute causes and liabilities.

In the case of few layers in bridge deck surfacing, the following additional key-points must be considered for dispute resolution (Castro 2004):

- Bridge asphalt pavement must provide good evenness, skid resistance and protection of the deck from the action of traffic, atmospheric agents, de-icing salts; a deck protection (waterproofing layer) is often used.
- Asphalt pavement on concrete bridges may suffer the following particular types of damage: waterproofing blisters, courses reciprocal flow (waterproofing-deck, waterproofing-pavement, etc.), slippage, fatigue cracking, rutting, bleeding, scabbing, surface degradation, etc.
- In the hypothesis of null bond (between deck and pavement), the larger the modulus (of asphalt concrete), the smaller the traction strains (in the bottom of the mix); therefore, Porous European Mixes, having low moduli, can have conspicuous traction strain.
- In the hypothesis of total bond (between deck and pavement), due to the large difference in modulus between deck and pavement, high shear stresses develop and there is a high risk that this bond will disappear over the time.

In the light of above-mentioned facts the following analysis procedure can be outlined:

1. Assess friction course condition.
2. Assess binder course condition.
3. Assess the condition of the other layers.
4. Assess the condition of the tack coats between layers and of the membrane over the bridge deck.
5. Check for the drainage of water from the bridge deck.

Typical testing procedures make use of coring and trenching.

METHODOLOGY - PART II - JURIDICAL AND ECONOMIC STRUCTURE OF THE PROBLEM

In this section, economic and juridical issues related to defects in inside layers are analysed. Note that, in this case, a special issue pertains the chain of liability among the different subjects of the construction process (agency, agency engineer, contractor), especially if the i-th course must be milled and so also the courses laying above (friction course, etc.). Moreover, these features are becoming increasingly important due to the growing importance of wearing courses (long life pavements) and to the fact that friction courses on bridge decks are often considerably more expensive than conventional asphalt concrete pavements.

The key-points of the Italian juridical structure in this field are reported below:

- Art. 1664 of the Civil Code (c.c.): fair pay adjustment for unforeseeable causes. Two related principles: invariance of the contractor performance and invariance of the payment.

- Art. 10 of the Italian Bid/Contract general provisions (DMLLPP n.145 del 19.04.00: fair pay adjustment in case of substantial modification of work quantities).
- Art. 1667c.c.: contractor must warranty for defects (nonconformities and/or insufficiencies with regard to the state-of-the-art). Two types of defects are defined: defects that do not threaten stability "*non inficiano la stabilità*" and defects that threaten stability. In the first case (do not threaten stability), there are two possibilities: (a) pay adjustment and (b) removal of the defect. In the second case (do threaten stability), there is only one possibility: contract resolution with pay adjustment. The warranty for defects continues also after the acceptance (in general, for two years) but only for hidden defects.

On the basis of the above-reported factors and of the state of the art, the following hypotheses have been here outlined (see Figure 1):

(a) First layer involved – milling not needed
The *1st layer* is defective but milling is not needed; Pay adjustment is estimated on the basis of given (if any in the contract) methods or on the basis of life cycle cost analysis, LCCA – see next section). Consideration of both functional and mechanical properties is needed.

(b) First layer involved– milling needed
The *first layer* is defective and milling and reconstruction is needed; the contractor has this liability.

(c) Inside layer involved - milling needed and detectable defect undetected by the agency engineer. Joint liability.
The *i-th (i≠1) layer* is defective and milling and reconstruction of all the above pavement structure is needed; the contractor (of the i-th layer) singularly pays for milling and reconstruction of only the i-th layer; the milling and reconstruction of the above layers is an issue of joint liability with the agency engineer because the defect has been detected too late;

(d) Inside layer involved - milling needed and hidden defect undetected (defectiveness known or unknown by the contractor). Contractor has the liability for all.
The i-th (i≠1) layer is defective and milling and reconstruction of all the above pavement structure is needed; the contractor (of the i-th layer) pays for milling and reconstruction. In particular, it is assessed the liability of the contractor for having placed a course that it knew was defective; it is the case, e.g., of high RAP percentages contained in the mixture, without the necessary mix design.

(e) Inside layer involved - milling not needed- empirical formula for PA estimation suggested in the contract.
The *i-th (i≠1) layer* is defective but milling is not needed; pay adjustment (PA) is estimated on the basis of given methods (usually empirical) set out in the contract; in his case there is the issue of the real representativeness of such methods (is the estimated PA really the quantification of the of the money loss from the agency (and the users)?

(f) Milling not needed- empirical formula for PA estimation not suggested in the contract formula of PA

The *i-th (i≠1) layer* is defective but milling is not needed; PA is estimated on the basis of the LCCA, applied to the pavement (all the layers must be considered).

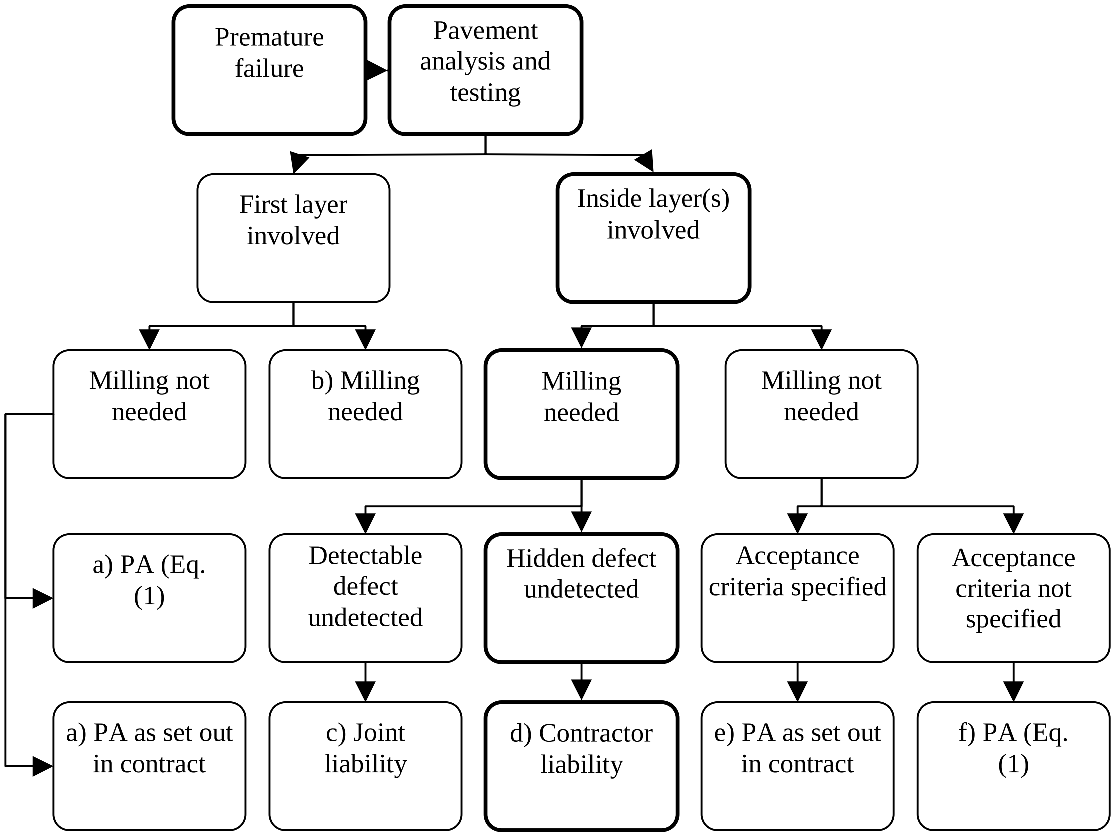


Figure 1: Simplified tree of liabilities and pay adjustment

METHODOLOGY - PART III - ALGORITHMS FOR PAY ADJUSTMENT AND LIABILITIES

This section deals with the proposal of a method for considering the above-mentioned cases in terms of PA. In order to pursue the above-mentioned targets, the algorithm should take into account:

- Surface and volumetric parameters for the friction course; only volumetric parameters for the other courses (in order to consider friction, drainability and similar surface performance).
- As-designed and as-constructed pavement (as a starting point in order to apply LCCA).
- The six cases above summarized and other occurrences if needed;
- The possibility of time delays.

The idea behind the following algorithm is that PA should compare all the costs incurred during the period over which as-designed (DP) and as-constructed pavement (CP) has been compared.

Under these hypotheses there is the possibility to assign to the as-constructed and the as-designed pavement the expected life and the effective work delay (see Table 1 and Figure 2); these factors (D, EB, ODP, ES, OCP) are the inputs of the algorithm below described, while the obtained output is the Pay Adjustment for each layer. In order to achieve this goal, Life-Cycle Cost Analysis (LCCA) is applied (Walls and Smith 1998). As is well known, LCCA is an analysis technique for evaluating the total economic worth of a usable project segment by considering initial cost and discounted future cost, such as maintenance, user, reconstruction, rehabilitation, restoring, resurfacing cost, over the life of the project segment.

For an engineering-economic approach to the problem, the following key-points are important:

- The initial cost of wearing courses ranges from 3 to 15 US$ per square metre, in relation to country, typology, thickness, etc.
- Wearing courses expected life ranges from 7 to 15 years, depending on traffic, climate, etc.
- Maintenance strategy includes crack seal, surface seal, mill and replace, patch and costs vary from 1000 to 30000 US$ for lane-Km.
- As road conditions become better, road administration costs prevail on road user costs, which become negligible; note that routine annual maintenance costs and user delay costs are often negligible if compared to agency costs; anyhow, this assumption must be checked for the single case.
- Discount rate (which depends on the difference between interest and inflation rate) fluctuate from 3.5% to 8% for the different states (OECD 2005); f) typical long-term values for interest and inflation rates are 0.08 and 0.04, respectively.

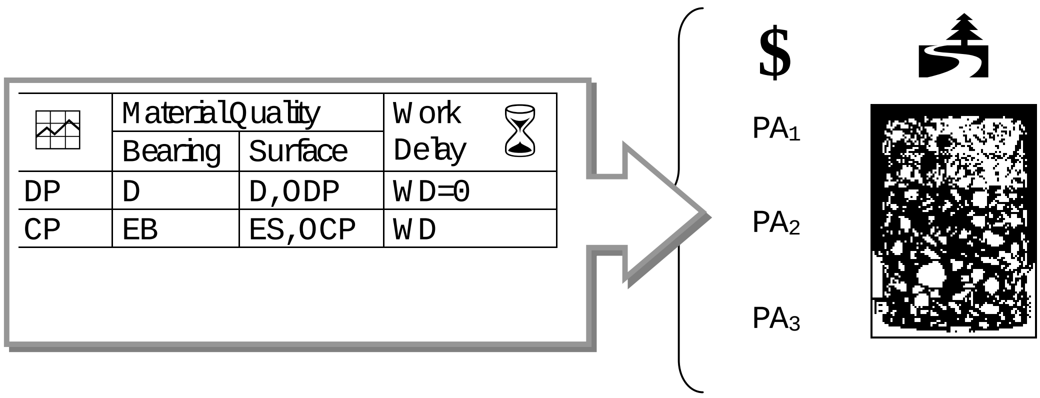


Figure 2: From material quality and work delay to the i-th pay adjustment (see Table 1)

In the light of above facts, the algorithm here proposed for the general case is (Praticò 2007, see figure 2):

$$PA=C_B\cdot[(R^D)\cdot(1-R^{ODP})^{-1}-(R^{EB})\cdot(1-R^{OCP})^{-1}]+C_S\cdot(R^D)\cdot R^{ODP}\cdot(1-R^{ODP})^{-1}+$$

$$-C_S(R^{EB})\cdot R^{OCP}\cdot(1-R^{OCP})^{-1}+C_S\cdot(-R^{ES}+R^D)- PC\cdot C_{DP}\cdot SD^{-1}\cdot W_D \quad (1)$$

where symbols and acronyms are below explained (see Table 1). Equation (1) is based on LCCA of road pavement; two conditions are compared: DP (as-Designed Pavement) and CP (as-Constructed Pavement, see Table 1). Both Bearing (B) and

Supplementary (S) properties are taken into account. Timeliness issues are considered through the factor W_D (Work Delay, days), The output of Equation (1) has the same units as the costs (C_B, C_S, e.g. €). When many layers and contractors are involved, a procedure for the estimation of factors liability is needed. In order to purse this objective, the following procedure has been here formalized (see Figure 3):

Step 1) assessing, for the i-th parameter, the importance I_i (tentative value=1/n, where i=1, 2, …, n):

$$0 \le I_i \le 1 \tag{2}$$

and

$$\Sigma I_i = 1 \tag{3}$$

Step2) calculating the Percentage of Defects PDi, for the i-th factor, where

$$0 \le PD_i \le 100 \tag{4}$$

step 3) calculating the Relative Liability L_{BRi} (where B stands for Bearing properties, R for Relative and i for i-th layer):

$$L_{BRi} = PD_i \cdot I_i \tag{5}$$

Step 4) derivating the liability L_{Bi}, where

$$L_{Bi} = L_{BRi} \cdot 100/\ (\Sigma L_{BRi}), \tag{6}$$

And

$$PA_{Bi} = PA_B \cdot L_{Bi}/100. \tag{7}$$

Note that it results:

$$\Sigma L_{Bi} = 100. \tag{8}$$

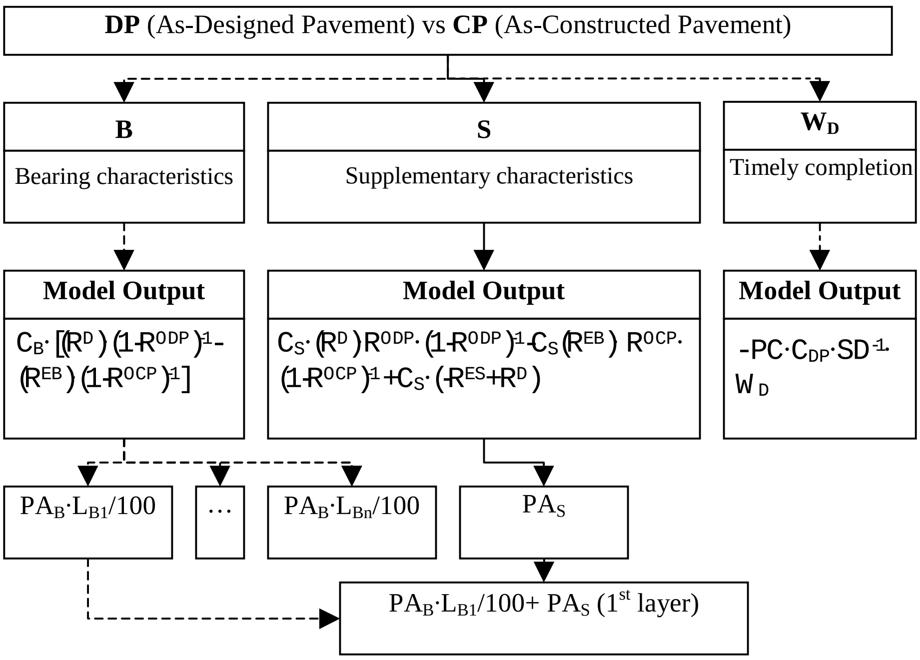


Figure 3: Pay adjustment and liabilities (see Table 1 and Equations 1–8)

Table 1: List of symbols and acronyms

B	"bearing" component of the pavement
C_B, C_S	Present Costs, referred to "B" characteristics or to "S" ones
CP	As-Constructed Pavement, actual pavement constructed by the contractor
D	Design life of the as-Designed Pavement; also called initial design life, it is the amount of time for which the chosen pavement design is expected to carry the traffic loads without the application of a global rehabilitation.
DP	As-Designed Pavement; desired pavement, as defined by the agency (buyer)
E, EB, ES	Expected life of the CP, general, for only B component, for only S component, respectively
I_i	Importance of the i-th parameter
INF, INT, R	Inflation rate, interest rate, $R=(1+INF)\cdot(1+INT)^{-1}$.
L_{Bi}	Liability
L_{BRi}	Relative Liability (i-th layer)
O, ODP, OCP	Expected life of successive resurfacing/reconstruction, general, of DP, of CP, respectively
PA	Pay Adjustment
PC	Project Criticality (dimensionless, default value=1)
PDi,	Percentage of defects for the i-th factor
S	Supplementary component of the pavement. It hasn't bearing properties.
SD	Scheduled Duration of the work (days)
W_D	Work Delay expressed in days (positive for late completion, negative for early completion)

EXPERIMENTAL APPLICATION: A CASE-HISTORY

A premature failure has been detected on a motorway in southern Italy. The following pavement structure has been detected:

1. First layer: PEM.
2. Second layer: HMA binder course .
3. Third layer: HMA base course; condition: good.
4. Fourth layer: granular base; condition: good.
5. Fifth layer: subgrade; condition: good.

Pavement surface condition was assessed thorough the procedure above formalized:

- Visual surface inspection (surface cracks rating in terms of frequency, surface area, shape, etc., see Figure 2).
- Visual inspection after coring and trenching (see Figures 4 to 9).
- In-lab testing.

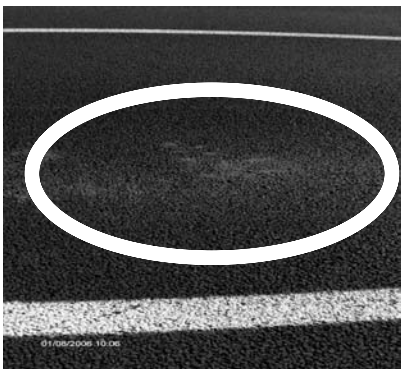


Figure 4: Surface condition: rutting, cracks (in the wheelpaths), water and fines bleeding

Figure 5: Slab extraction: PEM cracked, binder course strongly damaged

The slabs (1st and 2nd layer) extracted from the wheel path resulted significantly defective (binder course) in terms of mix consistency, aggregate grading, asphalt binder percent; a very irregular bridge deck was observed and monitored.

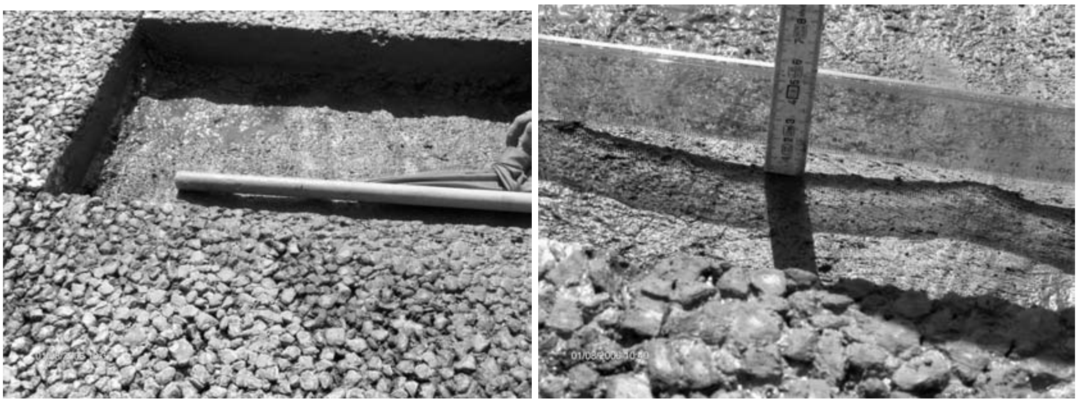


Figure 6: Evidence of a bridge deck rough and irregular

The cores (1st and 2nd layer), extracted in the shoulders, resulted in good conditions; on the contrary, the cores extracted in the wheel path resulted significantly damaged (especially for the binder course).

By referring to the binder course, all the cores presented air void contents greater than 8% and permeability greater than 0,0013cm/s.

Figure 7: Cores 1 and 2 extracted from the shoulders

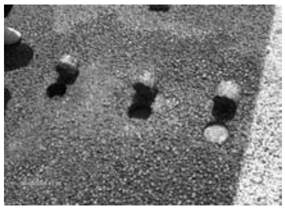


Figure 8: Cores 3 (right), 4, and 5 (left)

Moreover, some non-conformities in the methodology of applying the tack coat membrane to the bridge deck have been detected.

Figure 9: Slab and state of the bridge deck

On the basis of the in-lab experiments, the following additional findings have been found: (i) the PEM was always conforming; (ii) the binder course had a conspicuous moisture content; (iii) the membrane (on the deck) was always in good conditions; (iv) the bond between the membrane and the deck was mainly insufficient, with a very rough bridge deck and recurrent water patches; and (v) pavement condition all around the wheel path area was cracked with an incipient state of potholes formation.

According to the analysis above performed (Methodology – part II), in order to scan the possible causes the following main factors have been considered:

- Surface water drainage: water ponding was detected near transverse joints (in correspondence of bridge pillars). Vertical pipes on shoulders or joint cutting in the shoulders have been suggested.
- Bridge deck roughness: the roughness of the bridge deck has been charged in joint liability due to the practical impossibility to have a sufficient bond between membrane and deck.
- Bond between bridge deck and membrane: the condition of the membrane (thickness: 0.8cm) resulted satisfactory, but the bond between the bridge deck and the membrane resulted to be not fully conforming; the following main causes have been hypothesized: imperfect hot sealing, roughness of the bridge deck, traffic of heavy vehicles during construction, great difference in terms of stiffness between the membrane and the other layers. Nonconformities have been detected in the technique used for overlapping.
- Binder course and tack coat: on the basis of the tests performed on cores and slabs, three different classes of air void contents have been detected in the three lanes: first lane, AV>14%; second lane: AV>13%; third lane (opposite direction) AV>8%.
- A strong correlation has been detected between air void content (of the binder course) and surface distress (in the friction course).
- The following factors may have interacted with the high air void content: (a) the percolation of water through the PEM in the direction of the binder course; (b) the reduction of the modulus of the binder course, due to the high void content (when air voids increase from 5% to 11%, then relative modulus decreases from *circa* 1 to 0.6); and (c) related processes of stripping and therefore progressive disintegration of the binder course with consequences for the PEM.
- Friction course (PEM): rutting has been monitored (about 1cm on wheel path); the friction course appeared cracked in the wheel path. Water seepage out of cracks (water bleeding) has been detected and water and fine material appeared ejected from underlying layers through cracks in the HMA layer under moving loads (water pumping). According to the investigation above performed (Methodology – part III), water bleeding and pumping have been associated to a decreased skid resistance and structural support. Among the possible causes, several including poor drainage, underlaying failure and fines excess and dusty aggregates have been hypothesized. Though the presence, only in the wheel path, of bleeding of fines and water and cracks, tests on the friction course (PEM) resulted always conforming to the specifications set out in the contract.
- Multilayer design consistency: in the specifications set out in contract, the necessity of a tack coat has been clearly stated both for the sections on the bridge deck and the others. Design has been successfully checked for consistency.
- Anomalies in load conditions: operational speeds and load spectrum have been surveyed and resulted conforming to the road class and the design hypotheses.

- Weather conditions during construction: agency engineer did not report rain after the construction of the binder course and before the construction of the friction course.
- Other causes: other possible causes have been detected but their influence resulted unquestionably minor.

Table 2 summarizes the influence of the parameters above considered on the premature failure of the pavement (the procedure above formalized has been used, see equations (2) to 8). Only the relevant factors have been considered.

Table 2: Estimation of the influence of each cause on the premature failure of the pavement

Non-conformity	**I_i**	**PD_i**	**Relative Liability L_{BRi}**	**Liability percentage (L_{Bi}, rounded)**	**Liability**
a) Surface water drainage	0.1	34.5	3.5	10	Contractor
b) Roughness of the bridge deck	0.1	35.2	3.5	10	Contractor
c) Bond between membrane and bridge deck	0.1	69.6	7.0	20	Contractor
d) Binder course and tack coat between binder course and friction course	0.3	69.5	20.9	60	Contractor
e) Friction course	0.4	0.0	0.0	0	
Total	1.0	208.8	34.8	100	

Given the compelling schedule, the technical occurrence of stripping phenomena has been considered as the main support for the assessment of the hidden defects (cfr. the case f above described in Figure 1).

On the other hand, tests proved that reclaimed asphalt pavement have been used in the binder course, so violating contract specifications and *a fortiori* supporting for contractor liability.

In the light of above, the contractor was charged of milling and reconstruction of membrane, binder course, tack coat and friction course.

The following interventions have been concerted:

- Pipes in proximity of transverse joints, in order to facilitate the drainage and to mitigate the local barrier effect due to the joints.
- Milling of the existing pavement and full depth reconstruction.
- Use of anti-stripping additives also in the binder course.
- Minimizing air void content in the binder course.
- More accurate quality controls, especially for the bridge deck membrane and for the tack coat between layers.

MAIN FINDINGS

This paper outlines a model that aims to evaluate the real economic worth by performing a complex estimation of costs based on LCCA, and by assigning single liabilities based on the percentage of defects. On the basis of the performed study and according to the relative experimental validations, the following main conclusions can be drawn: (i) in acceptance procedures, defects and anomalies can be related to construction problems and are very difficult to be detected without specific disruptive investigation thorough cores and trenches. Analyses and testing can proceed *layer-by-layer* ; (ii) from a juridical and economical point of view two key-factors must be identified: who is liable of what and how much does he pay in the case a pay adjustment is needed; (iii) the first issue depends on the potential to detect the defects before laying the above layer(s); and (iv) the second subject can be solved by using empirical formulas or by recurring to a better estimate of the real cost for the agency through the concept of life cycle cost both for surface and volumetric defects. A model has been here formalized and validated. More research is needed into model optimization and validation.

REFERENCES

Castro, M (2004) Structural design of asphalt pavement on concrete bridges. *Canadian Journal of Civil Engineering*, **31**, 695–702.

Emery, S (2006) Available online: http://www.geocities.com/profemery/pavement.html#stripping

Highway Research Board (1970) *Special Report No. 113: Standard Nomenclature and Definitions for Pavement Components and Deficiencies*. Washington, DC: Highway Research Board, National Academy of Sciences.

Kandhal, P S and Richards I J (2001) Premature failure of asphalt overlays from stripping: case histories. *In: Annual meeting of the association of asphalt technologists*, Clear Water, Florida, March.

Lavin, P (2002) The effects of dusty aggregates towards stripping in asphalt pavement. *In: The Asphalt Institute Spring Meeting*, Woodlands, Texas, 14 April.

Long, A and Ioannides, A (2007) Performance of Permeable Bases. *In: 86th Transportation Research Board Annual Meeting*, Washington, DC, 21–25 January.

Organisation for Economic Co-operation and Development (OECD) (2005) *Economic evaluation of long-life pavements, Phase 1 Report*.

Praticò, FG (2007) Quality and timeliness in highway construction contracts: a new acceptance model based on both mechanical and surface performance of flexible pavements. *Construction Management and Economics*.

Schaus, L and Tighe, S (2007) Performance-Specified Maintenance Contracts: Canadian Case Study. *In: 86th Transportation Research Board Annual Meeting*, Washington, DC, 21–25 January.

Turochy, R and Parker, F (2007) Comparison of Contractor and State Transportation Agency Quality Assurance Test Results on Mat Properties of Hot-Mix Asphalt Concrete: Findings of a Multistate Analysis. *In: 86th Transportation Research Board Annual Meeting*, Washington, DC, 21–25 January.

Walls, J III and Smith, M R (1998) Life-Cycle Cost Analysis in Pavement Design, Interim Technical Bulletin, Report No. FHWA-SA-98-079, Federal Highway Administration, Washington, DC.

INNOVATIVE REVENUE-SHARING SCHEME FOR PUBLIC–PRIVATE PARTNERSHIPS IN INFRASTRUCTURE PROJECTS

Santi Charoenpornpattana[1] and Takayuki Minato[2]

[1]*Construction Engineering and Management Program, Department of Civil Engineering, King Mongkut's University of Technology Thonburi, 126 Pracha-uthit road, Bangmod, Thung Kharu, Bangkok, 10140, Thailand*

[2]*Department of International Studies, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, 277-8563, Japan*

One of the most important issues in developing a balanced relationship between the government and private concessionaire is establishment of a fair revenue-sharing scheme. In practice, there are several conventional types of revenue-sharing schemes and each type has its advantages and disadvantages. Appling a suitable revenue-sharing scheme for the multiple-operator system (where there are a number of private concessionaires) will enhance system fairness and management efficiency. Using the scheme for every private operator in the system, however, may not be appropriate, as each operator may have different financial configurations such as investment cost, operation & maintenance cost (OMC) and expected revenue. The objective of this paper is to discuss the conventional approaches of the revenue-sharing scheme and to recommend an innovative and appropriate one to reduce risk burden and maintain the incentive of the private concessionaires to improve efficiency and service quality of project.

Keywords: infrastructure, public–private partnership, revenue-sharing scheme.

INTRODUCTION

Revenue sharing schemes between public authority and private concessionaire are one of the most critical issues in developing a balanced relationship between government and private investors in public-private-partnership (PPP) infrastructure development project. In practice, a public authority (governmental agency) awards a concession to operate a large-scale infrastructure normally to a single or limited number of private companies. This situation creates a monopoly condition where the opportunity to seek for excessive profit is given to a private concessionaire. The "excessive profit" means the portion of earning in excess of the minimum amount needed to attract investors to a project. In economics, it is referred as "rent", which will disturb the overall efficiency of the project (Milgrom and Roberts 1992). Therefore, the revenue-sharing scheme must be provided in order to take the excessive portion of profit back to public.

On the other hand, private sector's biggest concern over the infrastructure project is the risk it needs to take, especially demand risk. Risk in infrastructure development project is complex and huge (Flybjerg *et al*. 2003). No private investor would like to

[1] santi.cha@kmutt.ac.th

join an infrastructure project without any mitigation mechanism or support from government (Fishbein and Babbar 1996).

In Thailand, the government has recently been considering investments in several packages of infrastructure projects, such as a network of intercity toll ways and a mass transit network. During 2005–2009, the government planned to invest approximately 42.5 billion US dollars in such mega-projects. In specific, mass transit network in Bangkok needs 12.5 billion US dollars. To develop these projects, the government has two options for investment: public investment or PPP.

Both options have some pros and cons. With public investment, the government entirely invests in the projects using government budget (taxes) or borrowing from lending agencies such as the World Bank, ADB, JBIC and so on. The key advantage of public investment is that the government can take control of the direction of project, because the government is the sole owner and no private concessionaire is involved. However, the problem is that the amount of investment is quite large: using government budget would draw too much amount of money out of a very limited financial resource (the government budget size is approximately 30–35 billion US dollars yearly), while borrowing would increase public debt up to a critical level that would affect the country’s fiscal stability.

PPP has several advantages. With PPP, a private concessionaire invests at least partially in projects. For example, in a mass transit project, a private concessionaire would invest in “rolling stock”, while the government typically invests in civil works. Therefore, the government is freed from a financial burden. Furthermore, major investment and operational risks are transferred to private concessionaires. However, the major drawback of PPP is the contractual issues including responsibility sharing, risk allocation, government support schemes and revenue-sharing schemes between government and private concessionaires. These contractual issues need to be carefully designed to fit the investment environment such as project financial conditions, socio-political conditions and economic conditions.

A revenue-sharing scheme is one of the most important elements in the design of a PPP contract. The design of revenue-sharing schemes affects several important issues of infrastructure operation, namely financial return of government and private concessionaire, incentive to improve quality of service by private concessionaires and incentive to improve operational efficiency by private concessionaires.

This paper intends to clarify the existing revenue-sharing schemes typically used in projects around the world. Each model has its own advantages and disadvantages. Concepts and mechanisms of the mostly used models are discussed: the Percentage-of-Revenue model, Rate-of-Return-Cap model and Revenue-Cap model. Then an innovative revenue-sharing scheme is proposed with an underlying concept and mechanism.

REVIEWS OF REVENUE-SHARING SCHEMES

There are three typical models of revenue-sharing schemes being used in infrastructure development projects around the world: Percentage-of-Revenue, Rate-of-Return-Cap and Revenue-Cap (Alexander *et al*. 1996; Estache and De Rus 2000; Kerf *et al*. 1998; ETA 1988).

Percentage-of-Revenue model

With this model, a certain percentage of a project's revenue is returned to the public authority. The remaining portion will be given to a private concessionaire. For example, 30% of the total service fee collected is returned to the public authority. The authority may use this money to compensate for the construction cost already invested or for operation and maintenance. The money can be also used to invest in future extension of the infrastructure.

Disadvantage of this model is that revenue stream of the project is directly disturbed by the sharing mechanism. For example, 30% (which is substantial) of the total revenue is extracted from the private concessionaire's pocket. This obviously increases the break-even point and thus increases the financial risk of the project. In response, private concessionaire may increase the cost of risk in the project's financial appraisal. The additional cost of risk is eventually added into the service fee paid by users as compensation for the risk. If the fee is fixed by the authority and cannot be raised for the compensation, the project becomes unattractive to the private sector. In such a case, there would be little or no private companies willing to join the project. This condition worsens the competitive environment necessary for the bidding process.

This model is suitable for a project with low financial risk. An example is the extension of an existing transportation project. In such case, user demand can be determined without much uncertainty by using historical data from the existing project. Therefore, risk associated with financial return is very low. This model has been used in several infrastructure projects, for example, the Second Stage Expressway System in Greater Bangkok (extension from the First Stage Expressway).

Rate-of-Return-Cap model

The mechanism of this model is to limit the ceiling of the financial rate of return. If the rate of return is in excess of the specified level, the excessive portion must be given to the public authority. This mechanism directly addresses the "excessive profit" of the private concessionaire due to monopoly conditions created by the concession.

This model has a critical disadvantage. It potentially discourages private concessionaires from improving the operational efficiency of a project, for example, using better technology with a lower operation cost. For example, the concession contract may specify Rate-of-Return Cap for private concessionaire at 15% (Internal Rate of Return – IRR). If the IRR of a project is at a level equal or near to 15%, the private concessionaire would have no incentive to work more efficiently, because the additional return from improving efficiency would be finally given to the public authority.

Furthermore, the Rate-of-Return-Cap mechanism may create an incentive for the private concessionaire to behave opportunistically, for example, spending on unnecessarily expensive equipment in a way that could reduce the exceeding IRR down to the limit. In practice, such "opportunistic behavior" cannot be detected easily by the public authority.

Many infrastructure projects are using this scheme: the Mass Transit System in Bangkok is an example.

Revenue-Cap Model

With the Revenue-Cap model, the return for private concessionaires (before expenses) is limited to a ceiling value specified in concession contract. If the amount of user fee collected goes beyond the ceiling value, the exceeding portion will be returned to the public authority. This scheme intends to address the issue of private concessionaires' excessive profits.

The important disadvantage of this scheme is that it may lessen the incentive to improve the private concessionaire's quality of service, in such as cleanliness, speed of service and system security. An increase in service quality may grow user demand and result in additional revenue, but it comes with an additional cost. If project return is approaching or exceeding the revenue-cap ceiling, there is no point for the private concessionaire to invest in improving service quality without eligibility to take the additional return.

INNOVATIVE REVENUE-SHARING SCHEME

Motivation of this research is initiated from the idea that there should be a new revenue-sharing scheme that can minimize disadvantages of the revenue-sharing schemes explained above. Specifically, a revenue-sharing scheme that can maintain the incentive to improve operational efficiency and service quality without imposing excessive risk burden on the private concessionaire should be constructed. Most importantly, the new scheme must have the ability to regulate excessive profit of the private concessionaire, which is the original objective of revenue-sharing scheme.

Another important objective of this initiative is to build a revenue-sharing scheme that can be used effectively for the project with multiple operators responsible for multiple subsystems, such as a mass transit system where there is number of transit lines to be operated by different operator. Each subsystem has a unique financial configuration, such as amount of capital investment needed, financial structure, operational cost and revenue, etc. Furthermore, each subsystem may have different level of user demand. However, the usage fee for all subsystems may need to be the same rate for management purposes. These constraints often occur in some type of infrastructure such as a mass transit system. Therefore, subsystems with different financial configurations may match different revenue-sharing schemes, depending on the risk profile attached to it. Choosing any conventional revenue-sharing schemes and using it for all subsystems may not be appropriate. However, using different schemes for different subsystems may instead create problems over fairness among operators. Therefore, having a new revenue sharing scheme that can accommodate the explained conditions would be the solution.

Mechanism

From the objective requirements stated above, a new revenue-sharing scheme has been designed and constructed, as shown in Figure 1.

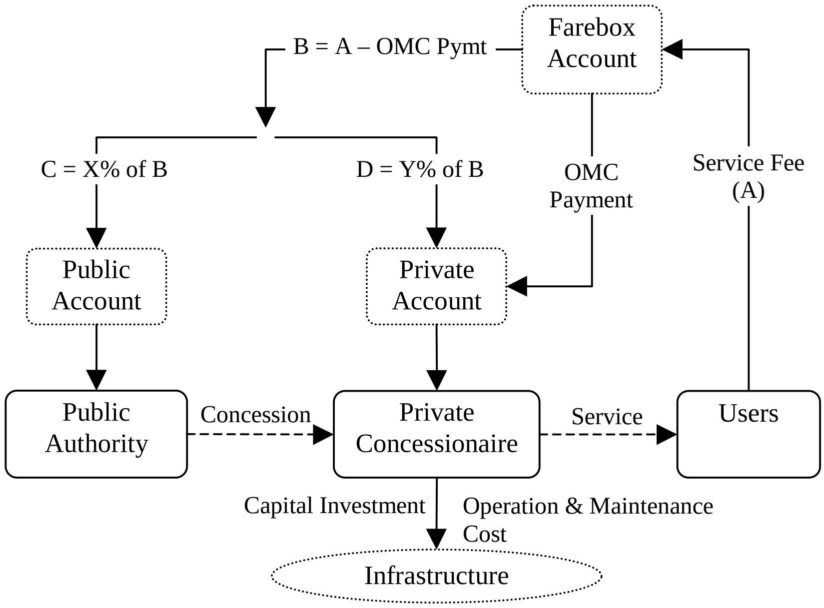


Figure 1: Mechanism for the new revenue-sharing scheme

The mechanism in Figure 1 works as follows:

1 Public authority awards a concession to operate the project to a private company called "private concessionaire". The concession normally specifies operational details, such as the right to collect a service fee, operation, expiry, etc.

2 The concessionaire makes a capital investment for construction/installation of the infrastructure.

3 After operation has commenced, the concessionaire begins to provide a service to users in exchange for a service fee. The fee collected from users will be transferred to different accounts along processes inside the mechanism as follows:

3.1 Initially, the fee will be totally transferred to the Farebox revenue. Then operation & maintenance cost (OMC) will be immediately paid to the concessionaire. The amount of the OMC payment is determined by the number specified in the concession contract, called "OMC Threshold". The threshold may be specified in term of usage volume, which can be converted to cash amount. For example, OMC Threshold of 100,000 users means the fee collected from the first 100,000 users will be totally given to private concessionaire as OMC payment. The threshold must be agreed by both the public authority and the private concessionaire, and must be specified in the contract. The point here is that the OMC payment is fixed. If the concessionaire could improve operational efficiency, it takes all the gain from improvement.

3.2 The revenue after OMC cost will be divided into two streams: for public authority and concessionaire. The sharing ratio between the two parties must be also agreed and specified in the concession contract. For example, a sharing ratio of 30:70 (public: private) means 30% of the revenue after

OMC payment is given to the public authority and the remaining 70% is given to the concessionaire.

Table 1 is an illustration of mechanism of the new revenue-sharing scheme. For illustration purposes, it is assumed that (1) the OMC Threshold is 100,000 users, (2) the sharing ratio is 50:50 (public: private) and (3) the usage fee is 20 baht per user.

Table 1: Illustration of mechanism for the new revenue-sharing scheme

Case	User Volume (person)	Farebox Account (Baht)	OMC Payment (Baht)	Public Authority (Baht)	Private Concessionaire (Baht)
1	50,000	1,000,000		0	1,000,000
2	100,000	2,000,000		0	2,000,000
3	150,000	3,000,000	20 x 100,000 = 2,000,000	500,000	2,500,000
4	200,000	4,000,000		1,000,000	3,000,000
5	300,000	6,000,000		2,000,000	4,000,000

In case No.1, where the number of users (50,000) is lower than the OMC Threshold (100,000), the revenue collected from the user (1,000,000) will be entirely given to the private concessionaire. In case No.3, where the number of users (150,000) exceeds OMC Threshold, the revenue given to the concessionaire is the OMC payment (2,000,000) plus 50% of the revenue after OMC payment (50% of 1,000,000 = 500,000). Therefore, the concessionaire will receive 2,500,000 baht in total, while the public authority has 500,000 baht. The payoff profile of private concessionaire is illustrated in Figure 2.

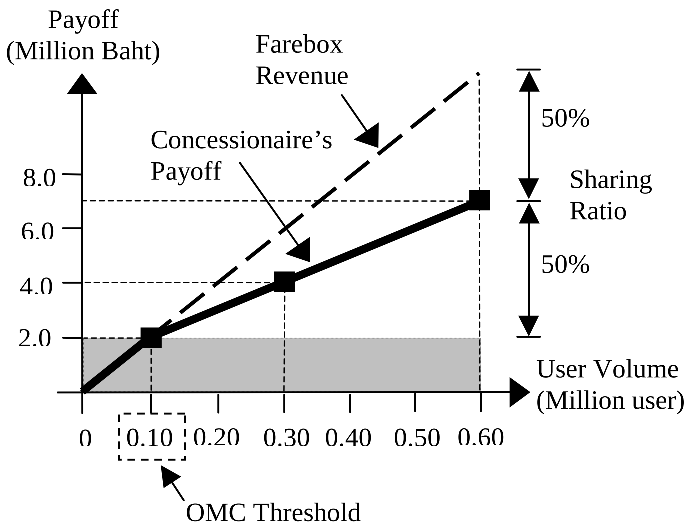


Figure 2: Payoff profile of concessionaire

Figure 3 illustrates four examples of payoff profile of the revenue-sharing scheme with different OMC Thresholds and Sharing Ratios. The profiles of Figure 3-A and B have an OMC Threshold of 0.10, while those of Figure 3-C and D are 0.30. On the other hand, profiles of Figure 3-A and C have a sharing ratio of <20:80> (public: private), while those of Figure 3-B and D are <80:20>.

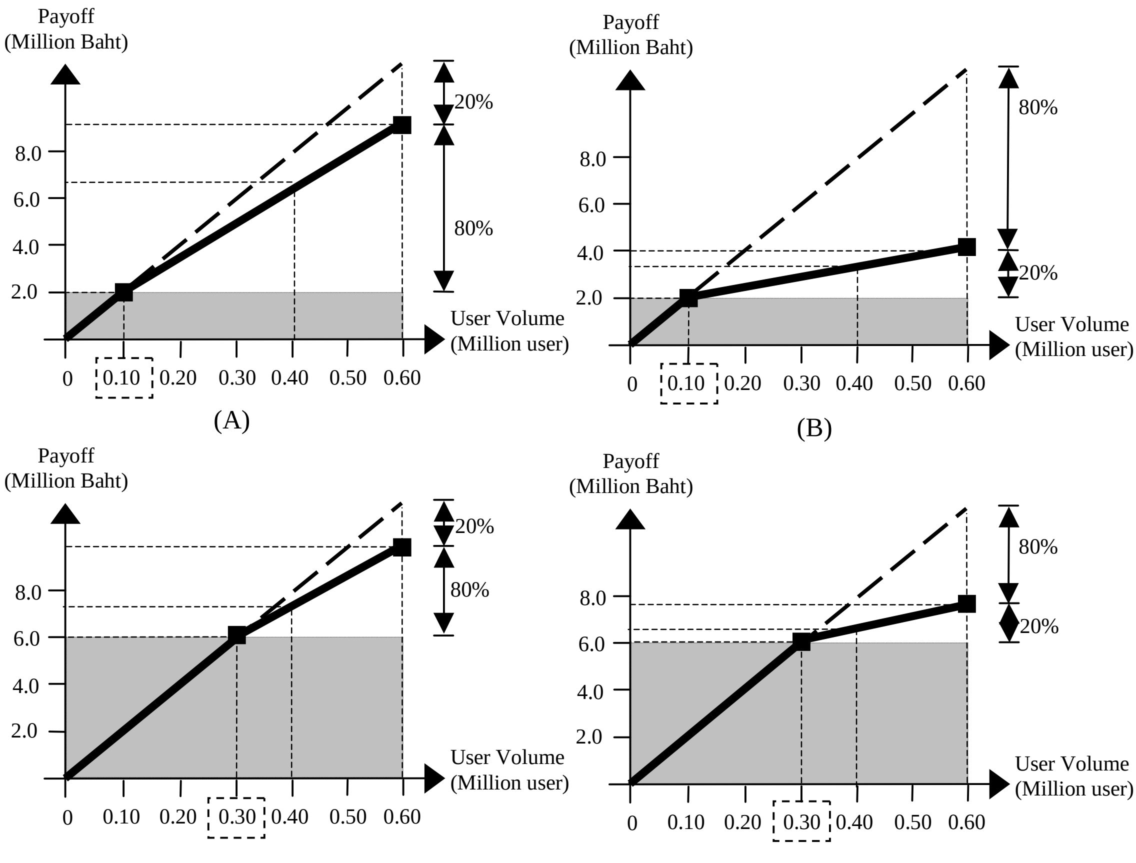


Figure 3: Comparison of concessionaire's payoff profile with different OMC Threshold and Sharing Ratio

It is obvious that the profiles with a higher OMC Threshold (Figure 3-C and D) give private concessionaires higher revenue than those with the lower threshold. For example, assuming the usage fee is 20 baht per user and the number of users is estimated at 0.4 million per day, the profile in Figure 3-D would give the concessionaire (0.3 x 20) + (0.1 x 20 x 20%) = 6.4 million baht, while that of Figure 3-B gives only (0.1 x 20) + (0.3 x 20 x 20%) = 3.2 million baht to the concessionaire. In Figure 3-B, revenue beyond 0.1 x 20 = 2 million baht must be shared with the government with the <20:80> ratio. In Figure 3-D, the concessionaire does not have to share any revenue with the public authority as long as the number of passengers does not reach the 0.3 million threshold.

Deciding a Sharing Ratio is also important. With a high ratio, the bigger portion of revenue from users beyond OMC Threshold must be given to public authority. For example, Figures 3-A and B have different Sharing Ratios with the same OMC Threshold. At 0.4 million users per day, the concessionaire profiled in Figure 3-A receives (0.1 x 20) + (0.3 x 20 x 80%) = 6.8 million baht. On the other hand, if the profile in Figure 3-B is used, the concessionaire receives only (0.1 x 20) + (0.3 x 20 x 20%) = 3.2 million baht. It is obvious that the sharing ratio is very influential to profitability of the concessionaire.

Key parameters

There are two key parameters for the mechanism: "OMC Threshold" and "Sharing Ratio". Their definitions and implications are explained as follows:

1 *OMC Threshold* is the number of users in which the service fee collected from them will be entirely given to the private concessionaire. The fee collected from users beyond the threshold must be shared according to the sharing ratio. Therefore, the higher the level of the threshold, the lower the financial risk the concessionaire takes.

   Therefore, the OMC Threshold should be at the level just sufficient for operation and maintenance cost. This has two implications. It would keep the concessionaire working hard to improve operational efficiency, while the financial risk of covering operation and maintenance cost becomes small. The public authority can utilize the OMC Threshold as a tool for risk adjustment.

2 *Sharing Ratio* is the ratio that is used to split revenue after OMC payment into two streams for the public authority and private concessionaire. The ratio is determined by profitability of the project. If financial appraisal indicates high profitability, the more revenue should be given to public authority. In such case, the sharing ratio may become 60:40 or 70:30 (public: private). By this concept, the concessionaire's excessive profit would be eliminated. The implication here is that public authority can utilize the Sharing Ratio Threshold as a tool for addressing the excessive profit problem.

In practice, the public authority and private concessionaire would negotiate for these two parameters. The new revenue-sharing scheme is applicable to multiple-subsystem projects with multiple operators. The subsystem with a high operation and maintenance cost (such as underground mass transit) and low user demand may be suitable for the high OMC Threshold and low Sharing Ratio. The subsystem expected to have low operation and maintenance cost (such as elevated mass transit) with high user demand may be suitable for the low OMC Threshold and high Sharing Ratio.

The new revenue sharing scheme proposed here is very flexible for adjustment to match a project's risk and profitability. It eliminates the key disadvantages of those conventional schemes explained earlier. Furthermore, in multiple-subsystem projects with multiple operators, the public authority can set the user fee at the same level across subsystems and use the two key parameters to fine-tune all subsystems to the same profitability level.

IMPROVEMENTS AND ISSUES FOR CONSIDERATION

From the concept and examples explained above, some key improvement and issues for consideration are as follows:

Improvements

1 The new scheme addresses the issue of revenue risk sharing between the public authority and the private concessionaire. The concessionaire does not have to share revenue with the public authority as long as the revenue is lower than OMC Threshold, which is the number of users that can generate sufficient revenue to compensate for operation and maintenance costs. Therefore, the concessionaire has a reasonably low risk of covering operation and maintenance costs, especially when compared to the conventional Percentage-of-Revenue model.

2 The new scheme also addresses the issue of incentive. The concessionaire still has an incentive to improve operational efficiency to reduce operation and

maintenance costs, because gain from the cost reduction is given to the concessionaire, as the OMC Threshold is fixed. Compared to the Revenue-Cap model, the new scheme better maintains an incentive to improve operational efficiency.

3. The incentive to improve service quality is also preserved, because there is no ceiling of revenue. The additional revenue derived from higher user demand because of better quality is not limited, compared to the Rate-of-Return-Cap scheme.
4. The new scheme is flexible and can be used for the Multiple-Operator system where financial configurations are different among subsystems and usage fees are fixed to be equal across the system. The public authority can use the two key parameters to fine-tune all subsystem to the same profitability level.
5. This scheme provide concessionaire with the reasonable and fair revenue-sharing scheme between public authority and concessionaires as well as among operators in the multiple-operator case. This environment would build up confidence for private sectors to invest in infrastructure development, which is the ultimate goal of the Public-Private-Partnership model.

Issues for consideration

The key issue to be carefully considered is the management of the scheme. Transparent measurement of actual user demand is very important, because the key input that determines the revenue given to both parties is the number of users. If the measurement is not performed correctly, then dispute between parties may occur very easily. However, this issue may be solved by modern revenue collection and information technology that is reliable and transparent. In large-scale systems, an independent regulatory unit may be established to take care of this issue.

CONCLUSION

This paper discussed three conventional revenue-sharing schemes: Percentage-of-Revenue, Rate-of-Return-Cap and Revenue-Cap. This paper also pointed out disadvantages of those conventional schemes, regarding risk burden and incentive to improve efficiency and service quality of the private concessionaire. Subsequently, it proposed a new revenue-sharing scheme that addresses the disadvantages of those conventional schemes. The new scheme tries to maintain an incentive to improve operational efficiency and service quality without transferring too heavy a risk burden to the private concessionaire. The new scheme can be used to maintain fairness among operators in the multiple-subsystem project, where each subsystem has different financial configuration as well as expected return. Finally, practical issues related to management of the new scheme are discussed.

ACKNOWLEDGEMENTS

The authors would like to thank Associate Professor Dr Nualnoi Treerat and Mr Thanee Chaiwat, School of Economics, Chulalongkorn University; Associate Professor Dr Chotchai Charoen-ngam, School of Engineering and Technology, Asian Institute of Technology; Dr Suthi Pasiphol, College of Innovation, Thammasart University; and Dr Poovadol Sirirangsri, Vice President of Bangkok Bank Plc for their contributions through comments and discussions on this paper.

REFERENCES

Alexander, I, Mayer, C and Weeds, H (1996) *Regulatory Structure and Risk and Infrastructure Firms: An International Comparison.* Policy Research Working Paper – WPS 1698, The World Bank.

Estache, A and De Rus, G (2000) The Regulation of Transport Infrastructure and Services: A Conceptual Overivew. *In:* A Estache and G De Rus (Eds.) *Privatization and Regulation of Transport Infrastructure: Guidelines for Policymakers and Regulators.* Washington DC: The World Bank.

ETA (1988) *The Second Stage Expressway System Contract*. Bangkok: Expressway and Rapid Transit Authority of Thailand.

Fishbein, G and Babbar, S (1996) *Private financing of toll roads. In: RMC Discussion Paper Series 117*. Washington DC: The World Bank.

Flyvbjerg, B, Bruzelius, N and Rothengatter, W (2003) *Megaprojects and Risk: An Anatomy of Ambition*. Cambridge: Cambridge University Press.

Kerf, M, Gray, R D, Irwin, Levesque, C and Talay, R (1998) *Concession for Infrastructure: A Guide for Design and Award*. World Bangkok Technique Paper No.339, The World Bank.

Milgrom, P and Roberts, J (1992) *Economics, Organization & Management.* New Jersey: Prentice Hall.

MISPERCEPTIONS ABOUT THE ROLE OF ARCHITECTURAL DESIGN AND RISKS IN A PPP PROJECT

Peter Raisbeck[1]

Architecture, Melbourne University, Melbourne, Victoria 3101, Australia

Southern Cross station is to date one of the largest PPP projects undertaken in Australia. This paper describes a survey of 12 executives working in the various organizations associated with the PPP consortium responsible for delivering the project. The aim was to better understand perceptions and misperceptions of the architect's role in relation to the management of project risks arising out of their initial design. The overarching framework used to govern the survey was the PPP lifecycle alongside the idea that architectural design can be viewed as a research and development activity rather than simply as a problem solving activity. In the media, the architect's design was perceived as having impacted on capital or recurrent costs when in fact it mitigated technical and operating risks and had little bearing on the projects substantial write-downs. This counters the perception that the activities of architects and their designs create more risks than they mitigate.

Keywords: architecture, risk management, design, public-private partnerships.

INTRODUCTION

As Public-Private Partnership markets have grown globally, there has been a corresponding rise in research focused on PPPs. This research is broad and ranges across a number of fields including construction management and economics, innovation theory and project management (Zhang 2005; Leiringer 2006). Much of this attention has focused on the experiences in the well-developed UK Private Finance Initiative (Dixon *et al.* 2005; Demirag *et al*. 2004). In contrast, other studies have focused on the role of PPPs in both developed and developing countries (Satyanarayna 2003; PWC 2005). Evident in this body of research is the idea that risk sharing and allocation is 'one of the most important factors for successful PPP/PFI outcomes'. As is often reiterated, 'this means allocating each risk to the party best able to manage it'. In theory, this approach 'reduces individual risk premiums and the overall cost of the project, because the party in the best position to manage a particular risk should be able to do so at the lowest price' (Akintoye *et al*. 2005: 463).

The focus on risk has led PPP research to take two main paths of further research. Evident in these trajectories is a top down approach to PPP research. One trajectory is financial in nature and examines how financial benchmarks are used to manage project risk in the PPP model; in these studies, risk premiums and the concept of value for money are seen as fundamental indicators in PPP projects (Dixon *et al*. 2005; Fitzgerald 2004). The second trajectory is concerned with the governance and management of PPPs (Koch and Buser 2006). These governance studies examine from above how to govern

---

[1] raisbeck@unimelb.edu.au

PPPs at different scales. These scales include the national policies and regulations, project networks, knowledge management and less often the supply chain frameworks that appear to govern PPPs (Akintoye 2003; Corry 2004; Duffield 2001; Grimsey 2002). Nonetheless, in a few studies an overarching and aerial view of PPPs is eschewed in favour of an approach that privileges the user or the “4th P” (Majaama 2005).

PPPs and architecture

In contrast to these predominant trajectories, the aim of this study was to pursue a different, in a sense bottom up, trajectory arising out of the PPP risk allocation concept. This trajectory of research involves examining the extent to which risks in the PPP model are managed from the bottom up via architectural design processes. This is important if PPPs are to successfully deliver local community infrastructure rather than economic infrastructure or infrastructure associated with large bureaucracies such as in the health sector.

The importance of architectural design as an integrative process in PPP projects is underscored by the history of PPP projects. As David Gann, argues “the solutions concept” emerged in the infrastructure projects in the 1980s. These “build-operate-transfer (BOT)” projects can now be seen as the precursors of today’s current crop of PPP projects (2005: 572). In this context, the importance of the architect’s role is also reinforced by Gann who argues that at the design stage the architect is the prime “systems integrator” in building projects (2005: 573). By virtue of their primary and traditional role as the designers of buildings architects are key to conceiving, devising and integrating together various processes of construction innovation (Burry 2003). However, more often than not architects are generally associated with the iconic design of a building: usually, its image and aesthetic. This is despite the fact that the architectural design of a particular a particular PPP (or indeed PFI) project over the longer term has an impact on how that project is perceived and branded. A project’s iconic image, the way in which it enables the branding of a particular place, can obviously affect its overall success in commercial terms (Anholt 2005; Sklair 2005).

Project history and context

This paper extends our research into Southern Cross Station, a hybrid social and economic infrastructure project in Melbourne Australia. The station is, to date, one of the largest PPP projects undertaken in Australia (Raisbeck 2006). In July 2002, the Civic Nexus consortium was awarded the contract for the station. In this deal, Civic Nexus will operate the station for 30 years, after which time the station will revert back to public ownership. The consortium, owned by ABN AMRO Australia, included Leighton Contractors, Daryl Jackson architects in association with the London-based Grimshaw architects Honeywell and Delaware North Australia, a retail and hospitality group. This paper summarizes our survey of 12 executives working in the various organizations associated with the PPP consortium responsible for delivering the project. These stakeholders included senior executive project managers, consulting engineers, financiers and contractors who worked on the project. In addition, pilot surveys alongside benchmark surveys were conducted with the project architects. All the interviews and the identities of the respondents were confidential.

In August 2002, the Victorian state government finalized its agreement with Civic Nexus at which point the station was valued at $350 million dollars and it was agreed that Civic Nexus would also build $350 million worth of adjoining developments. In return, the State government will pay Civic Nexus an annual fee of $AUD 34M. It was calculated that this fee would amount to the government paying $AUD 1762M, including inflation to the Civic Nexus over the 30-year concession period. During this time, Civic Nexus was to be responsible for maintaining the facility.

The initial strategy for the architectural concept for the station was deceptively simple. The geometry of the station's 'wave-like' roof was designed to capture and extract the diesel fumes expelled from the diesel trains using the station without recourse to mechanical ventilation. The primary issues that impacted on the construction of this design was the fact that the station had to operate as the roof was being constructed above it. This limited the construction methods available and, consequently, the roof structure had to be designed as a prefabricated entity with structurally stable components during its erection. Thus, as it was being constructed, the station's roof needed to be clear of the tracks and associated infrastructure including any overhead electrified wires. Despite these issues being anticipated in the Station's EOI documents, constructing the station was problematic and, by May 2004, Leighton indicated that the project would seriously impact on company profits. At this point in time, Leighton cited the confined working environment, site access issues, the 'demands of the franchisee train operators' and 'complex design variations' as the causes of their problems. On 6 May 2002, Leightons issued a statement to the Australian Stock Exchange indicating that these issues were resulting in time delays on the project and consequently Leighton downgraded its profit forecasts and eventually wrote down $AUD 150M on the project.

RESEARCH METHODOLGY AND SURVEY DESIGN

In the media, the Station's unique wave-like roof design – the element that constituted the project's design signature more than anything else – was often perceived to be linked to the contractors' write downs on the project. Indeed, one respondent in our survey exclaimed: "Architects! What would they know about managing risks? " In response, the aim of this research was to understand and corroborate the activities of the architects in relation to the management of project risks arising out of their initial conceptual design. For some contractors and consultants, architects and their designs are often perceived as being the source of risk rather than being seen as risk managers. This points to the disciplinary schism that often exists in the Australian building and property industry. Indeed, much Australian construction management research is framed in terms of a contracting perspective rather than from the perspective of design innovation. Consequently, in Australia, the role of architectural design and its relationship to different procurement models and risk management tends to be downplayed (Manley and Blayse 2004).

Project phases

To begin to understand how design is linked to risk in this context, the overarching framework used to govern the research design of the survey was the PPP lifecycle. This concept enabled us to ascertain what activities the architects undertook during each phase of this lifecycle. This helped us to structure the survey in order to identify what risks the architects were managing in each of these phases and how their management of risk was perceived by other stakeholders. The phases in the survey were defined in the following terms:

Phase 1: project development (including EOI, tendering/bidding)
This stage included up to the end of bidding: initial briefing and project analysis; conceptual design of project; formation of the project team; and design of the project's financial structure.

Phase 2: design development and documentation process
This stage included: the development of the conceptual design with users and consultants; integration of logistical needs with the design; and further integration of the project's construction costs.

Phase 3: construction
This stage included: the construction of the project; the resolution of further design issues as they arose; the ongoing negotiation of logistical issues with user groups; and the management of budget with construction costs of as they arise.

Phase 4: conclusion and operation forecast
This included open questions regarding the overall impact of the architect's involvement with the project. It also addressed issues regarding the likelihood of any future building maintenance and design works.

Using the above organizing framework, the survey instrument was developed as a matrix to understand how the activities of the architects were perceived. As described below, these activities were defined and the survey respondents were then asked how these activities either contributed to or mitigated various risks in the PPP lifecycle.

Defining architectural activities in the survey
In the survey, architectural design was defined as a research and development activity rather than as a problem solving activity. Hence, it is viewed here as a process of research in order to develop new forms and ideas about buildings. This approach conforms to recent studies in architectural theory which argue that design, especially architectural design, is a research activity in its own right. In this view, architectural design is seen as a process whose task is not to simply optimize buildings in either functional, spatial, material economic or terms. Instead, it is viewed as a means to research, explore and experiment with new forms and ideas about buildings. In other words, it is as an activity of research in its own right, which results in innovative solutions and customized products that respond to complex situations. Southern Cross Station can thus be regarded as a complex product in which the architects of the station used the project as an opportunity to research and develop new innovations in regards to environmental performance.

These ideas prompted us to look to studies of R&D teams in order to define the activities of the architects. The definitions of these activities were based on a previous study into teams in the biomedical area (Mann *et al*. 2005). Based on this work, we define architects as the "information brokers" who assist in "orchestrating cooperation and knowledge growth to achieve innovation outcomes" (Mann *et al*. 2005). This helped to clarify what it was the architects did in each phase of the project. In line with this in the survey instrument, we defined the activities of the architects in the following ways:

- Creating design knowledge: researching design ideas, initiating new design approaches and solving problems through design.
- Design monitoring: providing advice on design issues, ensuring the design meets aesthetic, architectural and spatial requirements, and ensuring the design meets established cost and planning levels.
- Design liaising and management: communicating and negotiating design ideas to the client group, communicating to project team, planning and coordinating with the project team, and engaging in activities to build relationships within the team.

A scale of zero to five was used to gauge these responses: zero indicating that the architects did not undertake the activity and five indicating that the respondent perceived that the architect undertook the activity a great deal.

The intent of the above definitions was to actively counter the perception that architectural design is an ephemeral and entirely subjective or aesthetic activity. In contrast, it is conceived as a unique and often one-off activity. An activity that, in this instance, created new knowledge that encompassed both exploitative and exploratory notions of innovation (Benner and Tushman 2003). From this perspective, the architect's initial design produced prior to the bidding decision can be seen as the result of exploratory innovation that they then refined after they won the bid using exploitative modes of innovation.

Defining risks in the survey

Defining risks in the survey was more straightforward than defining the activities of the architects. Definitions of risk are more readily understood and these were adapted from work in the area of project and risk management (Jaafari, 2001) and related to a number of project specific risks including financing (including cost estimate risks), technical, integration, and environmental and operating risks. These were described to the survey respondents in the following ways:

- *Technical and operating risks:* probability that the project will not perform to required technical standards or to its required functionality.
- *Environmental and energy risks:* probability that the project will have adverse environmental impacts beyond permitted limits or have excessive operating energy consumption.
- *Capital costs risk:* probability that funds allocated to the project will be insufficient or that project will run over allocated time and consequently incur further costs.
- *Recurrent costs risk:* probability that the forecast income from the project will be below expectations or that the facilities brand image is diminished.

Again, as with the activities of the architects, a scale was used to assist in quantifying responses. The survey instrument employed a scale ranging from negative five (greatly mitigated) through to zero (no effect) through to five (greatly added to). In the tables presented here, this has been converted to a scale that ranges from zero to eleven.

The pilot survey

The survey was piloted with a small number of respondents prior to the full survey of 14 respondents. The respondents to the pilot surveys were familiar with both the project and the PPP model itself. The pilot surveys assisted in ascertaining the length of the survey in time (most respondents were interviewed between 30 and 55 minutes). More importantly, the pilot surveys helped to confirm and modify the relevance of the above defining terms including the PPP project phases, architectural activities, risk categories as well as the wording of the open ended questions and the usefulness of the scales.

DISCUSSION OF RESEARCH RESULTS

Perceptions of risk and the architect's role

In order to examine perceptions about the architect's activities and their initial concept, a matrix based on the survey data was designed to analyse how well they mitigated risks.

This was designed to identify any significant correlations between the creation of design knowledge in Phase 1 and perceptions of risks or financial losses related to either capital costs or future operating costs. This analysis was important because when first announced the redevelopment of Southern Cross was broadly promoted, and indeed branded, as a place which would be ‘a state-of-the-art’ design (Das and Costa 2000) Consequently, during the course of its construction the project had received a great deal of media attention. Indeed, the station’s iconic roof design was often cited in the media as a primary cause of the difficulties encountered during construction.

The survey responses appeared to confirm the way we had defined the activities of the architects and the role which the architects undertook (Table 1). From the open interviews, the ongoing activities of the architects and their ability to manage risks throughout all phases of the project were also reinforced. This result counters the perception that the architects were only interested in creating a conceptual or strategic design and that the architects did little to manage this design after Phase 1. Such a perception appears based on the premise that that once an architect creates a design, they then have little involvement with a project's construction management. This creates the more alarming impression that architects create risk in their designs that contractors then manage and “mop up.” However, as discussed below, all the respondents in our survey appeared to agree that throughout the projects phases, the architects were actively involved in creating design knowledge, design monitoring and design liaison and management.

Architect’s role and recurrent and capital costs

The executives in our survey perceived the architect’s initial design as mitigating operating and technical risk more so than either mitigating or exacerbating risks related to cost. This is borne out in the correlation analysis. Creating design knowledge in Phase 1 was negatively correlated with creating technical and operating risks (Pearson Correlation $r = -0.691$). In the media, one widespread perception was the concern that the station’s roof would not act to remove exhaust fumes as it was intended. However, our analysis suggests the opposite perception might be a factor. In other words, by creating unique design knowledge, by addressing issues of environmental performance in the Station’s roof design, technical and operating risks in the longer term are decreased. Surprisingly, creating design knowledge in Phase 1 was not associated with increased capital and recurrent cost and these appear appeared to be less significant (Pearson Correlation $r = -0.564$ and $r = -0.633$ respectively).

In Phase 2, the architects felt that they were still creating design knowledge whilst the other respondents saw this as having been primarily created in Phase 1. During this phase, the survey respondents felt that the architects were not creating as much design knowledge as they had in the second phase of the project. In contrast, the architects themselves felt that they were creating more design knowledge in this phase than in Phase 1. This is perhaps because during Phase 2 the architects were actively working with both the structural engineer and the steel fabricators to realize the initial conceptual design. Nonetheless, the survey respondents tended to agree that design monitoring, liaison and management increased in Phase 2 and then decreased slightly in Phase 3 the documentation period. This would suggest that the executive stakeholders tended to see the architect’s role as one that is primarily concerned with creating the initial conceptual design.

Table 1: Executive stakeholder perceptions of architectural design activities (means reported; 5 max)

	Architects	Others
Phase 1 Activities		
Creating Design Knowledge	4.50	4.00
Design Monitoring	3.25	3.67
Design Liaison and Management	3.00	3.44
Phase 2 Activities		
Creating Design Knowledge	4.75	3.38
Design Monitoring	4.75	3.79
Design Liaison and Management	4.25	3.83
Phase 3 Activities		
Creating Design Knowledge	3.50	2.68
Design Monitoring	4.50	2.95
Design Liaison and Management	4.00	3.09

In Phase 2, it could be argued that the architects perceived that they had actively been engaged in what might be called systems integration by undertaking design liaison and management. This is because in Phase 2 the most significant correlations were between the activity of design monitoring and technical and operating risks (Pearson Correlation r = - 0.606) and integration risk (Pearson Correlation r = -0.686). This suggests that the more the architects actively monitored and co-ordinated the more technical, operating and integration risks were minimized. This is also reinforced in Phase 3 in which design liaison and management appeared to have some correlation with decreasing integration risks (Pearson Correlation r = - 0.617) and more significantly decreasing capital cost risks (Pearson Correlation r = -0. 788). This correlation indicates clearly, despite the small sample size of this survey, that the activities of the architects may have lessened capital cost risk rather than increased them on the project. This is underscored by the fact that a number of the survey respondents recognized that the architects had worked to protect the commercial viability of the project in functional terms.

Not surprisingly, the architects themselves felt that they foresaw a number of risks early in Phase 1 of the project including risk concerning the projects, constructability. Moreover, the architects were extremely concerned that the contractors had not employed a time programmer and they were not party to cost planning decisions at an early stage of the process. Perhaps this is why across all the project phases there appeared to be some correlation with the lessening of integration risks with an increase in design monitoring activities (Pearson Correlation r = -0 .694).

Table 2: Executive stakeholder perception of risk created or mitigated by architects (means reported: 1 greatly mitigated; 6 no effect; 11 greatly added to)

	Architects	Others
Phase 1 Risks		
Technical and Operating	3.25	5.70
Environmental and Energy	3.50	5.10
Integration Risks	4.00	5.78
Capital Costs	5.50	5.85
Recurrent Costs	4.25	5.15
Phase 2 Risks		
Technical and Operating	1.25	5.00

Environmental and Energy	2.25	4.63
Integration Risks	2.25	5.00
Capital Cost Risks	2.75	6.13
Recurrent Cost Risks	5.25	5.42
Phase 3 Risks		
Technical and Operating	1.00	4.91
Environmental and Energy	2.50	5.18
Integration	4.25	5.14
Capital costs	3.50	5.64
Recurrent Costs	5.00	5.05
Overall Risks		
Technical and Operating	2.25	4.17
Environmental and Energy	1.75	4.58
Capital costs	4.00	6.71
Recurrent Costs	4.00	5.13

Overall, survey respondents more directly concerned with project delivery were obviously satisfied with the way in which the architects had managed risks. Table 2 indicates that the activities of the architects only managed to reduce or mitigate risks on the project to slight degree (range: 4.17 to 6.71). These results were confirmed in our interviews in which many of the survey respondents indicated that many of the risks, and financial losses, accounted on the project arose due to having to construct the station's roof whilst it was still operating. This was compounded by poor cost planning and programming alongside the unforeseen complexities of negotiating with a number of stakeholders who had jurisdiction over the station such as bus and rail operators. Consistent with the data gathered in relation to the architect's activities, the perceptions of how the architects managed risks seem to be more favourable than less favourable.

Table 3: Executive stakeholder perception of overall risks created or mitigated by the architects in Phase 2 (means: 1, greatly mitigated; 6 no effect; 11 greatly added to. Architects: Respondents A and B)

Risk category	**Project Executives**													
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
Technical and Operating	1.5	1	3.5	3	2.5	2	7	3	8	5	4	8.5	10.5	3
Environmental and Energy	2.5	2	2.5	3	2.5	6	6	2	3.5	6	1	8.5	10.5	4
Integration	1.5	3	2.5	6	6	2	4	2.5	6	5	2	8.5	10.5	5
Capital costs	1	4.5	3	5	3.5	3	6	5	5	8	6	11	11	7
Recurrent Costs	4.5	6	4.5	3	4.5	3	2.5	5	6	5	6	10.5	11	4

Naturally, the architects themselves felt that their activities had significantly reduced project risks as had, most of the other key decision makers on the project. A small number of respondents felt that the architects had significantly added to the project risks (respondents I, L and M). This appeared to be the case with those project executives responsible for the Facilities Management and ongoing operations of the project after delivery. These respondents did not work with the architects during the design and design development stages of the building. Moreover, at the time of the survey, some parts of the building were still being commissioned and this may have influenced their criticism of the architects.

Taken together, both the descriptive statistics and the correlations indicate that the architects were able to develop an innovative conceptual design and then manage the risks associated with this design throughout the procurement process. In this project it was the capabilities of the architects to monitor this design and to communicate, plan, and negotiate various aspects of this design with other team members that was most important. This seems to be in accord with Gann's concept that architects are systems are "systems integrators" with a significant role in leading processes of design and construction innovation construction (2005). Such a view is at odds with other AEC professions and disciplines and this may be because perceptions of innovation is different for architects than contractors. Ankrah and Langford argue that the organizational culture of architects is quite different to that of contractors (2005). For example, they argue that architects have a greater tolerance of ambiguity than contractors do, and that for architects power is to be found in skills and expertise. For contractors it is to be found in the fostering and development of relationships. From this perspective, this research indicates that it is important to focus on the ways in which architects use their skills and expertise in relation to both create innovative conceptual designs and then to manage risks in the building procurement process.

FURTHER QUESTIONS

What the above results suggest is that the initial conceptual design despite its innovative features had very little bearing on project risks across the project. Whilst it was perceived by some, particularly in the media, that this initial design may have impacted on various risks this survey of project executives indicates that it in fact mitigated technical and operating risks an had little effect on capital or recurrent costs. Perhaps this was because they recognized that the architects had little direct control over cost planning. This is surprising given the fact that the contractor wrote down $150 million dollars on the project and promoted the idea to the media that design variations was one of the reasons for this loss. However the analysis of this project points to a range of issues that led to these write-downs, not the least being the mispricing of risk in the project at an early stage of the project. Whilst these general conclusions might appear to be favourably biased towards the architects but the general consistency of the responses of our survey's respondents points to the effectiveness of their activities.

This study, limited as it is, establishes that the activities of the architect were critical in managing the risks that arose out of the initial design. It points to the idea that architectural design is an activity that is often called upon to mediate between issues of overarching urban governance and fundamentals of financial risk. How do we manage the risks created by innovative designs? In the PPP model, where should the initial design and the further elaboration and creation of design knowledge take place? Should this be before or after the bidding process? When a company or organization chooses a particular procurement model, how should the role of the architects be considered? For example, would the contractors have written down so much on the project if the architects had more input into time and cost planning decisions? Whilst these questions may appear unnecessarily rhetorical, they point forward to considering further the role of architects in the procurement process. How should the role of the architect be accounted for in studies and theories of procurement?

CONCLUSIONS

In this project, the architects created a design that required a number of significant construction innovations. If we are to regard architects in having a role that creates new knowledge through an exploratory process of design, how is this to be factored into production theories of construction? Moreover, it is clear from this study that further research could be conducted that examines how the architects, contractors and facility mangers manage design and innovation in complex projects; in other words, how do they integrate various systems and sub-systems each project? It is important to answer this type of question because contractors are called upon more and more to deliver both the services and some of the solutions for a particular facility during the concession period. Overall, these ideas are useful because they point to the importance of theorizing the building procurement or production process as one that should take into account the role of architectural design. But more importantly this points to the need to understand the procurement process in greater detail from the bottom up rather than the top down in order for the PPP model to be itself better designed in the future.

REFERENCES

Akintoye, A, Hardcastle, C *et al*. (2003) Achieving best value in private finance initiative project procurement. *Construction Management and Economics*, **21**, 461–70.

Akintoye, A, Bing, L, Edwards, P J and Hardcastle C (2005) Critical success factors for PPP/PFI projects in the UK construction industry. *Construction Management and Economics*, **23(**463), 459–71.

Anholt, S (2005) *Brand New Justice: how branding places and products can help the developing world*. London: Elsevier.

Ankrah, N A and Langford, D A (2005) Architects and contractors: a comparative study of organizational cultures. *Construction Management and Economics*, **23**, 595–607.

Benner, M J and Tushman, M L (2003) Exploitation, Exploration, and Process Management: The Productive Dilemma Revisited. *Academy of Management Review*, **28**, 238–56.

Burry, M C (2003) Notes on the Non Standard: numerical and architectural production. *In: Non Standard Architectures*. Paris: Centre Georges Pompidou.

Corry, D (2004) New Labour and PPPs. *In:* A Ghobadian *et al*. (Eds.) *Public-private partnerships: policy and experience.* Houndmills, England; New York, NY: Palgrave Macmillan.

Das, S and Costa, G (2000) Huge Upgrade For Spencer Street Station. *The Age*, 29 February.

Demirag, I, Dubnick, M and Iqbal Khadaroo, M(2004) A Framework for Examining Accountability and Value for Money in the UK's Private Finance initiative. *The Journal of Corporate Citizenship*, **15**, 63.

Dixon, T, Pottinger, G and Jordan, A. (2005) Lessons from the private finance initiative in the UK Benefits, problems and critical success factors. *Journal of Property Investment & Finance*, **23**(5), 412–23.

Duffield, C F (2001). *An evaluation framework for privately funded infrastructure projects in Australia*. Department of Civil and Environmental Engineering. Melbourne, Australia, The University of Melbourne.

Fitzgerald, P (2004) *Review of Partnerships Victoria provided infrastructure: Final report to the Treasurer*. Melbourne: Growth Solutions Group.

Gann, D, Brady T, Davies A, (2005) Can integrated solutions business models work in construction. *Building Research and Information*, 33/6, 2005, 572 (571-579).

Grimsey, D and Lewis, M K (2002). Evaluating the risks of public private partnerships for infrastructure projects. *International Journal of Project Management*, **20**(2), 107–18.

Jaafari, A (2001) Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management*, **19**, 89–101.

Leiringer, R (2006) Technological Innovation in PPPs: incentives, opportunities and actions. *Construction Management and Economics*, **24**, 301–8.

Manley, K and Blayse, A M (2004) Key Influences on Construction Innovation. *Construction Innovation,* **4**, 143–54. (Despite its title, this paper makes no mention of design the role architects play in managing construction innovation.)

Majamaa, W (2005) Evaluation of proposals for PPP projects from the perspective of a group of rational consumers. *In: 11th Joint CIB International Symposium*, 13–16 June, Helsinki.

Mann, Bain, Pirola Merlo and Hirst (2005) The ARC Study: Design and Method for Studying R&D Teams and their leaders and Bain, Mann, Atkins and Dunning, (2005) R&D Project Leaders: Roles and Responsibilities. *In:* Mann *et al.* (eds.) *Leadership, Management and Innovation in R&D Project Teams*. Westport, CT; London: Praeger.

Price Waterhouse Coopers, (2005) Delivering the PPP promise: a Review of PPP issues and activity. Price Waterhouse Coopers. Available online: www.pwc.com/igu

Raisbeck, P (2006) PPP financing, architectural design, and risk mitigation in Melbourne's Southern Cross Station project. *Joint International Symposium of CIB Working Commissions W55/W65/W86 Construction in the XXI century: Local and global challenges,* Rome, 18–20 October.

Satyanarayana, N, Kalidindi and Thomas, A V (2003) Private sector participation road projects in India: assessment and allocation of critical risks. *In:* A Akintoye, M Beck and C Hardcastle (Eds.) *Public-private partnerships: managing risks and opportunities*. Malden, MA: Blackwell Science.

Sklair, L (2005) The Transnational Capitalist Class and Contemporary Architecture in Globalizing Cites. *International Journal of Urban and Regional Research*, **29**(3), 485.

Zhang, X (2005) Criteria for Selecting the Private-sector Partner in Public-Private Partnerships. *Journal of Construction Engineering and Management,* 631.

ARE PUBLIC–PRIVATE PARTNERSHIPS EFFECTIVE INFRASTRUCTURE DEVELOPMENT STRATEGIES?

Michael J. Garvin[1]

Myers-Lawson School of Construction, Virginia Tech, 200 Patton Hall, Blacksburg, VA 24061, USA

Public-Private Partnerships (P3) have emerged over roughly the last two decades as a popular strategy for infrastructure development worldwide. Initiatives within the United Kingdom, Australia and Canada are well known while the use of private capital for infrastructure projects within emerging economies has become a global trend. Within the US, P3 arrangements have been used somewhat selectively thus far, but their momentum is building as states put enabling legislation in place to permit public-private initiatives and as "successes" such as the recent leases of the Chicago Skyway and the Indiana Toll Road are reported. Proponents of P3's tout numerous advantages while detractors often claim that the marginal benefits rarely materialize or that they are obtained at too great an expense. Thus, the question arises, are P3s effective as infrastructure development strategies? A research initiative is underway to answer this question in the context of the US. Thus far, the work has: (a) synthesized notable literature regarding P3s and infrastructure development, (b) developed a framework to measure the effectiveness P3s at the programme and project level, and (c) begun a longitudinal case-based study of both P3 programmes and projects where the framework is applied. Preliminary results are presented and discussed. While the research has not progressed far enough to make categorical conclusions, the early findings suggest that P3 initiatives in the US have had limited effectiveness and that the future success of these endeavours may depend upon establishing national guidelines for their implementation and assessment.

Keywords: contracting, infrastructure development, procurement, programme/project delivery, public–private partnerships.

INTRODUCTION

The public-private partnership (PPP or P3) movement is arguably the most significant, worldwide trend in the public sector. The United Kingdom's *Private Finance Initiative*, which began in earnest in 1992, has facilitated the delivery of nearly 800 projects valued at over £54 billion ranging from car parks to schools to tolled highways to power plants (HM Treasury 2007). Similarly, Australia's *Partnerships Victoria* programme has contracted 16 projects representing roughly $4.5 billion in capital investment since 2000 (State Government of Victoria 2007). Outside the developed world, the use of private capital for infrastructure projects within emerging economies has become quite common where financially challenged public administrations look toward the private sector to develop basic infrastructure (Esty 2003). In fact, a survey of a dozen national governments across the globe in the late 1990s indicated that a significant majority of the respondents expected "that the most successful government structure in 2010 will be one in which government focuses on policy and project/supplier management, allowing the private sector to deliver most

[1] garvin@vt.edu

traditional public services." (Economist Intelligence Unit 1999). Indeed, the prediction made by the survey's respondents seems on its way towards realization.

Within North America, Canada has seen its fair share of P3 activity within its provinces. A notable project is the Confederation Bridge, which was a design-build-finance-operate arrangement that established a fixed link between the mainland and Prince Edward Island. Another is the lease of the 407 Express Toll Route (ETR), where in exchange for nearly Cdn$3 billion a private sponsor leased this facility from the government for 99-years. Within the United States, activity in this market has started to pick up. Currently, over 20 states have enabling legislation in place that permits some form of public-private initiatives on state transportation projects (FHWA 2007). In addition, the recent leases of the Chicago Skyway and the Indiana Toll Road have attracted the attention of governments to investors (Gribbin 2006; Florian 2007). Still, only a few states – Indiana, South Carolina, Texas and Virginia – are truly active on this front.

Clearly, the interplay between (a) the general reluctance of public agencies and governments to raise taxes, (b) the emergence of private sector participants which are willing and most capable of handling the risks and delivering the services of infrastructure, and (c) the realization of pension fund and institutional investment managers of the attractiveness of privately financed infrastructure projects to the risk/return requirements of their clientele is driving the progress of this market. P3 activity or output, though, does not provide any indication of the effectiveness of such programmes or projects. Performance measurement theorists will certainly suggest that outcomes are far more important than output. Moreover, infrastructure is fundamentally a public good (infrastructure clearly is not a "free" good, as many consumers perceive since its costs are veiled by the variety of mechanisms used to fund its development and management). As such, the public has a right to expect that it provides a satisfactory level of service, has a reasonable price, and allots its benefits and costs equitably. This begs the question, are P3 outcomes better than or at least equal to more traditional infrastructure development and management strategies? Moreover, what is necessary for this market to develop and realize its potential? These questions motivate this research initiative, which is subsequently described and which benefits substantially from the groundbreaking work already done by various governments, agencies, professionals and researchers.

BACKGROUND

Characterization of P3

Any discussion regarding the P3 movement must start with an attempt to characterize and define this approach to project and/or service delivery. Unfortunately, a concise characterization is elusive. Kingsley and O'Neil (2004) presented a conceptual framework and model designed to assist with the development and measurement of P3 initiatives, but their model is founded upon the premise that P3 arrangements are truly "partnerships" where each partner has the perspective that their organizational identity and competitive advantage are enhanced through participation in the partnership. Examination of definitions offered by various parties such as the US National Council for Public-Private Partnerships, the Canadian Council for Public-Private Partnerships, and the National Government of the United Kingdom suggest that this is not the type of arrangement either sought or established in the infrastructure sector (Garvin and Chiara 2006). In truth, most P3 guidance documents emphasize the significance of clear and enforceable partnership “conditions”. In fact, one of the preconditions for success identified by the International Monetary Fund is whether the quality of services is “contractible”. Given these circumstances, this working definition is proposed for the infrastructure community: *A Public-Private-Partnership (P3) is a long-term contractual arrangement between the public and private sector where mutual benefits are sought and where the private sector provides operating services and/or puts private finance at risk.* Notably, this definition excludes the transfer or sale of infrastructure assets or services to the private sector. The transfer of an asset or service qualifies as “privatization”; this distinction is more than semantic. P3 arrangements are governed by contracts and the accompanying body of contract law. Privatizations are regulated enterprises where the governance and legal structures are quite different.

As Orr (2006) indicated, cash-strapped governments are quick to proclaim that private capital is a solution to infrastructure funding shortfalls and is an often used argument for P3 arrangements. This claim by governments is somewhat contentious. Since P3 projects typically require user fees, a government certainly has the capacity to use these fees as the principal security for the financial arrangement while also offering its general creditworthiness as secondary security. One would expect that the cost of capital for such an arrangement would be lower than the cost that a private sponsor could obtain, even if tax-exempt status is granted. Gribbin (2007), however, has argued that innovative private financing debt-equity structures can free these assets from the conservative bond investor clientele. Indeed, he may be correct. The holders of government bonds or even private tax-exempt bonds have relatively conservative appetites for risk, which introduces fairly conservative methods for assessing value. Alternatively, an entirely private debt-equity structure introduces investors with higher tolerances for risk, which will in turn tend to generate more liberal appraisals of asset value. While the cost of capital may indeed be higher, the perceived value of the asset under scrutiny is also likely higher. This notion was confirmed in an interview with an executive from the Fluor Corporation, who indicated that he would prefer to avoid tax-exempt status on privately financed projects because this typically introduces layers of financial conservatism that he viewed as unnecessary (personal communication, Herb Morgan, 26 April 2006).

Nonetheless, the state and society should demand more than an economic premium for granting the private sector the right to develop and/or operate facilities that are generally public goods. Indeed, the private players in this arena have the expertise, the agility, and the incentive to provide more – a higher quality of service, a reasonable price for the service, faster availability of the service, and net contributions to the environment. Otherwise, their expertise is wasted. Moreover, the risks of transferring these responsibilities to the private sector could be too great.

Relevant literature

State guidance documents

The United Kingdom has issued a variety of documents regarding P3. One of the most significant is the *Value for Money Assessment Guidance* document, which describes in great detail the procurement process for such projects. In Australia, the *Partnerships Victoria* document provides similar information. The central proposition of these guidelines is that P3 arrangements should always be considered for infrastructure development or service delivery, but they should only be pursued if they deliver **value for money**, which is loosely defined as the optimum combination of lifecycle costs and quality to meet user requirements. Each document attempts to clarify the process for conducting such assessments. Indeed, the manuscripts have a spirit about them, but they are very mechanical in nature. Similarly, Australia's *Contract Management Policy* document outlines the steps necessary to ensure proper allocation and management of the responsibilities and risks during a P3 concession. Likewise, Canada's *Public Sector Comparator* document is a self-help guide for government officials at all levels who may be considering P3 arrangements. As with the comparable UK and Australian documents, it aims to provide a tool for assessing the viability of a P3 project by comparing its benefits and costs with those of the project if it were delivered in a more traditional way. One interesting difference between the jurisdictions is the nature of governance. In the UK, for example, the national government has shaped the policy and fashioned the conditions that define the "partnerships" formed between the public and private sectors. Alternatively, in Canada, many public-private partnerships have been struck by provincial or local governments without a well-defined national policy or framework. The situation in the United States is identical to the one in Canada.

Other literature

The academy has produced numerous articles about P3. Many have addressed key, general components of P3 arrangements such as Chua *et al*. (1999). Zhang (2005) identified a variety of success factors and ranked them in order of importance through surveys of industry personnel and academics. Bing *et al*. (2005) grouped success factors into five categories: (a) effective procurement; (b) project implementability; (c) government guarantees; (d) favourable economic conditions; and (d) accessible financial markets. Other articles have looked more closely at specific P3 initiatives. Akintoye *et al*. (2003) used interviews to determine how best to achieve success in Private Finance Initiative (PFI) projects in the UK. They found that identifying and properly allocating risk, curtailing cost escalation, improving project completion times, introducing innovation, and reducing maintenance costs can help lead to successful projects. They also identified several challenges to achieving best value, such as the high cost of management, lengthy negotiations, and complex contractual relationships. Russell and Nelms (2006) discussed the implementation of Canada's *Public Sector Comparator* guide; their conclusion was that in practice a lack of clarity in the tool opens it up to a number of unintended uses as well as a variety of abuses that result from agenda-driven applications. Additional work has focused substantially on the risks of P3 projects. Froud (2003) discussed the risks of PFI projects and how the private sector must genuinely assume the risks given to it. He argued that value for money could only be achieved if private sector expertise, innovation, competitive efficiency, and risk transfer can overcome the increased transaction, contracting, and negotiation costs – not to mention the additional need for economic profit. Quiggin (2005) detailed aspects of risks in P3 arrangements, including the notion that partnering creates new risks. Finally, Loosemore and Ng (2007) identified the public and private risks in P3 arrangements and suggested how to best allocate them.

RESEARCH DESIGN

Fundamental propositions of the work

This endeavour takes a very particular view of the P3 movement, which is based upon past and current research by others *and* the writer's involvement in case-based research of large-scale infrastructure projects over the last decade. Many of these cases are reported in Miller (2000) and Miller (2002) (a number of cases have also been converted into educational case studies, which are available from the writer's website). These influences have produced two fundamental propositions that constitute the basis of the current work.

- **Proposition I –** the basic objective of a *P3 Programme* is to nurture the development of this market and to sustain its existence. To do so, a P3 Programme must establish equilibrium among four environments: (1) the state, (2) society, (3) industry, and (4) the market. Figure 1 depicts this notion conceptually.
- **Proposition II –** *projects* are the operational expressions of any P3 Programme. As such, any particular project can either maintain the equilibrium of the overall programme or distort it. Further, the collective performance of all projects will determine whether the P3 Programme is effective as a strategy or policy for infrastructure development & management. Each P3 Project should seek to provide a marginal improvement in one or more of the following areas: (a) quality of service; (b) price/cost of service; (c) time of service availability; (d) level of environmental impacts; and (e) equitable distribution of social benefits.

Certainly, neither proposition is entirely original or groundbreaking. Indeed, the equilibrium framework illustrated in Figure 1 incorporates concepts presented by Lessard and Miller (2000) regarding the risks of large engineering projects and by Linder and Vaillancourt Rosenau (2000) about the terrain of P3 arrangements, as well as other fairly familiar socioeconomic notions. Still, these propositions represent an important synthesis of ideas derived through grounded research, from relevant literature, and from common thought. Moreover, they provide the reader with a clear perspective of the underpinnings of the research, which found the entire programme.

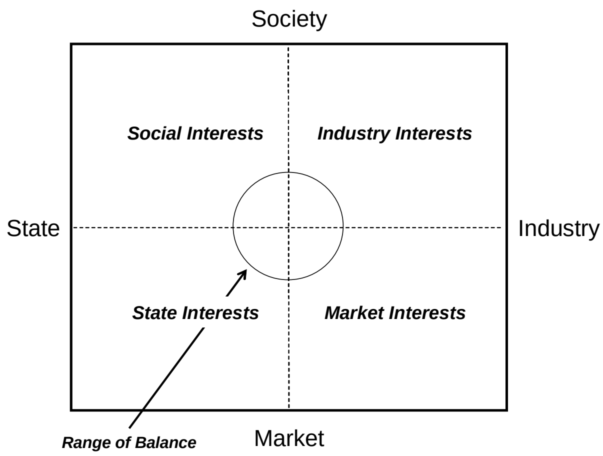


Figure 1: P3 equilibrium framework

Figure 1 shows four continuums (state, society, industry and market), four quadrants (social interests, industry interests, market interests and state interests) and a central space dubbed the "range of balance". The "state" is the elected or allotted body governing a jurisdiction. "Society" is the citizens living and working within a jurisdiction. "Industry" is the enterprises engaged in providing services & goods to the state and society within the jurisdiction. Finally, "the market" is the financial system that allows investors to exchange wealth and risk through time.

This framework is relatively flexible; in fact, a more general illustration of the relationships between the continuums and the quadrants may help to explain its relationship to P3 programmes. The extreme positions are found at the corners of the framework. For instance, when activities of the state and society are heavily, or even absolutely, aligned "pure socialism" exists. Similarly, absolute state and market alignment produces "big government", absolute market and industry alignment results in "unbridled capitalism", and absolute social and industry alignment relies on "pure philanthropy". The point of this description is not to comment upon the costs/benefits associated with these extremities, but rather to "calibrate" the reader's perspective.

The depiction in Figure 1, however, does take a particular stance; it advocates that the long-term success of a P3 programme depends heavily upon establishing a balance between the interests of the state, society, industry and the market. More than likely, creating a discrete "point" is not feasible, particularly since P3 projects are likely to scatter themselves into the various quadrants since each project's conditions will vary. *However, the central hypothesis of this work is that the scatter of a programme's projects must cluster within the 'range of balance'*. Otherwise, the programme will ultimately suffer from **bias** toward a particular quadrant (such as a clustering in the social interests region) or from **instability** if no clustering is observed at all. Thus, the equilibrium framework helps to establish the boundaries for the overall programme, and it provides a platform for plotting the general location of each project and evaluating a programme's evolution.

Research methodology

The research is continuing the longitudinal, case-based approach to study the effectiveness of P3 Programmes & Projects, and the framework just discussed provides the "basis" for the evaluation of effectiveness. As with all grounded or case-based research, the importance of construct validity (establishing correct operational measures for the concept under study) and reliability (demonstrating that the operations of a study are repeatable) are paramount to this endeavour (Yin 1994). Construct validity will be maintained by using multiple sources of evidence: (a) source documents such as enabling legislation, programme guidelines, RFP's and concession agreements; (b) third-party documents such as periodical articles, archival literature or position studies or papers; and (c) structured interviews with the principal parties involved. These various sources of information should "triangulate" to produce a credible chain of evidence. Reliability is achieved by applying a consistent study protocol throughout.

This approach, however, is not without its limitations. Foremost, the number of contemporary P3 initiatives in the US is limited, and while sampling would certainly help to solidify the findings of the research, to do so, would require expanding the scope of the study beyond the US. While this is clearly possible since the worldwide use of P3 is substantial, it is not necessarily feasible in the short-term, if the thoroughness of the methodology is to be maintained. In addition, experience to date suggests that obtaining the cooperation of principal stakeholders for structured interviews can be difficult since often these arrangements are politically 'charged'. This condition hinders, but does not prevent, establishing a credible chain of evidence.

Analytical techniques

The P3 Equilibrium Framework provides the perspective for the research, but it does not provide the tools necessary for *measurement*. At the programme-level, the analysis measures the *institutional environment* in two areas: (a) the soundness of the enabling legislation that typically initiates any P3 Programme and (b) the viability of the executive guidelines established as a result of the legislation. Table 1 depicts a variety of elements and issues for consideration as well as the impact of each when evaluating a programme's enabling legislation.

Table 1: Enabling legislation template

Element	Issue		Impact	Element	Issue		Impact
	Source of definition	Solicited Only	–		Comparative analysis	Not addressed	→
		Unsolicited Allowed	↘			Required	←
Scope of Work or Service	Limitations	Mode restrictions	←			Required and process defined	–
		Geographic restrictions	↙	Acquisition &	Selection method	Undisclosed	↗
		Project/service delivery restrictions	↙	Procurement		Competitive	–
	Sources Allowed	All	–			Negotiated	↗
Financing		Private only	↘		Approvals	Legal exemptions obtained	–
	Allowances or Exclusions	Tax-exemption allowed	↗			Permits/property acquired	–
		Diversion to public/general funds allowed	↙			3rd-party consultants allowed	–
	Method of establishment	Publicly driven	←		Auditing process	Undisclosed	→
		Privately driven	→			Disclosed	↙
User Fees		Negotiated	→	Concession		Disclosed/adequately defined	–
	Management	Not addressed	→	Management	Termination rights	Undisclosed	↗
		Escalation controls	–			Unlimited	↙
		Revenue sharing with state	←			For Cause	–

Table 2: P3 project appraisal template

Element	Issue		Impact	Element	Issue		Impact
	Established demand	Yes	–		No-Compete Provisions	Allowed and absolute	↘
		No	↘			Allowed w/ exclusions	–
Market Conditions	Competing facilities	Yes	↖		Performance measurement	Clear & objective	–
		No	→			Absent	↗
	Project type	Greenfield	–			Vague	↙
		Brownfield	←		Conditions for renegotiation	Clear & objective	–
	Project scale	Large	↗	Concession		Absent	↗
		Moderate	→	Management		Vague	↙
Socio-Environmental		Small	–		Termination provisions	Clear & objective	–
Conditions	Demographic impact	Diverse	–			Absent	↗
		Distinct	→			Vague	↙
	User Fees	Affordable	↖		Facility return provisions	Clear & objective	–
		Reflect 'cost' of service	–			Absent	↗
		Long-term plan	–			Vague	↙
	Financial/technical benchmark	Yes	–		Quality & Innovation	Readily apparent	✓
		No	↗			Difficult to judge	X
	Competition	No	↗		Price	Readily apparent	✓
		Comparable scope	–	Project Performance		Difficult to judge	X
Acquisition & Procurement		Price and other factors	–		Service availability	Readily apparent	✓
		Factors other than price	↗			Difficult to judge	X
	Selection criteria & process	Transparent	–				
		Objective	–				

Legend: – No movement from origin; → Toward industry/market interests; ← Toward social/state interests; ↙ Toward state interests; ↖ Toward social interests; ↗ Toward industry interests; ↘ Toward market interests; ✓ Positive impact on P3; X Negative impact on P3

The ‘impact’ column illustrates the general direction of movement away from the equilibrium framework’s origin for a given condition; this is a ‘likely’ impact, so judgment is necessary to determine if the likely ‘vector’ is indeed correct for the case at hand. To illustrate, consider the element *scope of work or service*, which has several issues identified. For the issue “Source of Definition/Unsolicited Allowed”, an impact vector points to the right and down. This suggests that if the enabling legislation permits the state to receive unsolicited proposals for P3 arrangements where the scope of work or service has been defined by the private sector, then the locus of the P3 Programme would move right and down from the overall framework’s origin. The skew is down since an unsolicited project will require a reliable revenue source to generate the required ROI; therefore, this condition would push the programme toward *market interests*. A similar template exists for evaluating executive guidelines. In many ways, the executive template determines whether “holes” in the enabling legislation are filled or not by the agency responsible for the conduct of the programme. Ultimately, the programme-level assessment gauges whether a P3 Programme “gets off on the right foot” or not by identifying the general location of the origin.

At the project-level, the more general aspects of the programme become operational and therefore are more detailed. Thus, this stage of the analysis considers the project details of five major categories: (a) market conditions, (b) socio-environmental conditions, (c) acquisition & procurement process, (d) concession management, and (e) project performance, as illustrated in Table 2. Each category has a particular focus, and its criteria are similar to those used to evaluate a programme. For instance, evaluation of the *acquisition & procurement process* focuses upon determining whether or not this process preserves the state/society’s interests while also attracting private industry and introducing market forces. Several basic principles are fundamental to this balance such as scope definition, transparency, and competition. Garvin (2003) discusses these principles further.

The *project performance* category, however, is unique among all of the categories. This category does not ‘move’ the location of a project within the quadrant space. Instead, it either **reinforces** or **weakens** the P3 strategy for infrastructure development. If a P3 Programme’s projects do not produce tangible improvements in service quality/innovation, competitive or equitable prices for such service, and reasonable progress in service availability, then the viability of the approach itself is questionable, regardless of whether the proper balance has been struck.

Similar to the programme-level templates, this analytical tool supports locating a project within the equilibrium framework’s quadrants. For instance, consider “Acquisition & Procurement/Selection criteria & process/Transparent". This aspect of the template measures the selection process’ transparency – the notion that all stakeholders in the acquisition system, particularly the private respondents, can see and understand the acquisition/procurement process prior to its execution or prior to making a commitment to participate. A transparent system maintains the current equilibrium, while a less than transparent one will move the equilibrium toward state interests since this is likely to provide the state tremendous discretion in its selection of a vendor. Once all of the elements are assessed, a project can be located within the quadrants. As subsequent projects are evaluated, a cluster should develop.

Some might demand more “precise” measurements. This is not necessary, nor likely. First, the framework is intended to serve as a guide to channel the assessment effort not as an instrument to pinpoint an exact location. Second, quantifying all of the factors involved and establishing correlations between them would be a monumental, if not impossible, task. Moreover, its complexity could easily diminish its credibility since such an effort would undoubtedly create a "black-box". The techniques employed must be accessible to all of the stakeholders involved. Otherwise, the results of the research will not transfer as widely and as deeply as desired.

Case studies
Some of the cases being used in this research are shown in Table 3; they are categorized as either first or second-generation programmes or projects. This separation allows an interesting by-product, the appraisal of learning over time.

Table 3: Selected case study programmes & projects

First Generation		**Second Generation**	
Programmes	**Projects**	**Programmes**	**Projects**
California AB680	Santa Ana Viaduct Express	–	Chicago Skyway Lease
	SR 91 Express Lanes	–	Indiana Toll Road Lease
	SR 125 South	–	Las Vegas Monorail
	Mid-State Tollway	California AB 1467	–
Virginia Highway Corporation Act	Dulles Greenway	Trans-Texas Corridor	TTC-35
			I-69/TTC
Washington Public Private Initiatives	SR 18 Corridor	Virginia PPTA Initiative	I-81 Improvements
	SR 520		Pocahontas Parkway
	Puget Sound Congestion Pricing		Route 460 Improvements
	Tacoma Narrows Bridge		

EXAMPLE P3 PROGRAMME & PROJECT ANALYSIS

California's AB 680 Programme & Projects

In 1989, California launched one of the United States' first P3 initiatives since World War II to confront transportation funding shortfalls. Bob Poole of the Reason Foundation, among others, suggested that California might consider having the private sector propose and finance transportation projects (Poole 1988). Soon after, Assembly Bill 680 (AB 680) was enacted; in sum, the bill gave the California Department of Transportation (CalTrans) the authority to award up to four demonstration franchises to private firms. At least one project each had to be located in Northern and Southern California. The franchises would grant exclusive rights to finance, design, construct and operate toll transportation facilities. A proposed project could not utilize any state or federal government funds in the financial package. Finally, franchise holders would be allowed to receive a 'reasonable' rate of return, although a definition of 'reasonable' was not given by the legislation. Any monies beyond this would be required to be applied toward debt principle balances or paid into a State Highway Account.

Subsequently, CalTrans developed a procurement process to solicit interest, qualifications, and conceptual proposals from respondents. In 1990, CalTrans received eight conceptual proposals and selected four projects: (a) the SR 91 Express Lanes, (b) the Santa Ana Viaduct Express (SAVE), (c) SR 125, and (d) the Mid-State Tollway. The SR 91 Express Lanes was the only project to proceed quickly. By 1995, the project had installed four lanes within the median strip of 10 miles of SR 91, an existing eight-lane state route, at a cost of $126 million; the base rate of return expected by the project's developers was 17%. These lanes functioned as High Occupancy Toll (HOT) lanes, where passenger cars with a single driver can pay to utilize the express lanes while high occupancy vehicles can use the lanes free of charge. Interestingly, the project's developers obtained a very favourable "no-compete" provision in the concession agreement, which prevented the Orange County Transportation Authority (OCTA) or CalTrans from making any transportation improvements within a specified region. By 2001, OCTA began to view this no-compete provision as a tremendous constraint to transportation service in the region. Instead of legally challenging this provision, OCTA purchased the Express Lanes back from the developer in 2002 at a price of $207.5 million.

Of the remaining three projects, only SR 125 survives. It is a $411 million project to construct a 4-lane toll road in the San Diego metropolitan area, with an anticipated return on investment of 18.5%. After a lengthy process to obtain environmental permits and political consensus, construction began in May 2003 with an expected completion date of June 2006. Construction delays have pushed the anticipated opening date to June 2007, and the developer has requested that CalTrans extend its concession period from 35 to 45 years to facilitate obtaining "a reasonable return on its investment". CalTrans has yet to officially grant this request.

Programme & project analysis

The AB 680 Programme was a first generation effort to introduce substantial private involvement in infrastructure development and finance. Notwithstanding its good intentions, it stands as a relatively meagre P3 example, as the subsequent analysis will demonstrate.

Programme evaluation

The programme's structure and boundaries were established by the AB 680 legislation and CalTrans' subsequent execution plan. The assessment of the programme follows:

- Scope of Work or Service: very limited address – the projects had to provide transportation service, and would be unsolicited proposals. Loose geographic restrictions were created. Overall, these conditions forced the private sector to search for opportunities that would generate revenues in excess of their capital and opportunity costs. This situation pushes the locus right and down.
- Financing: specifically addressed in the legislation – no state or federal funds allowed; this also required potential respondents to find revenue generating possibilities that would produce an adequate return. These conditions push the locus right and down.
- User Fees: explicit discussion of user fees was not included; however, the disclosure of the private developer's desired rate of return and the requirement that receipts collected in excess of this would contribute to the debt principle balance or a state highway fund suggests an implicit plan to manage these fees. However, the state did not define what it considered a reasonable rate of return; thus, private developers were given the burden of proof that the rate they desired was appropriate. These conditions push the locus right slightly.
- Acquisition & Procurement: This process was not discussed in the legislation, but CalTrans did issue very general guidelines as well as very generic criteria for evaluation. In defence of CalTrans, they were handed a very difficult task – to evaluate and select unique proposals. Comparative analyses between proposals were not feasible, and the source selection method & criteria,

although published, were so general that the selection team would have the ability to argue in favour of any of the proposals received. The necessary approvals for the projects were not in place, nor could they be, given the structure of the process. Overall, these conditions move the locus right.

- Concession Management: the legislation was silent on this subject, and CalTrans guidelines were vague in this regard. The issues were addressed subsequent to award, so the terms were negotiated as part of the concession agreement. This situation generally favours the developer since once selected they possess the negotiating leverage. These circumstances push the locus right and slightly up.

Project analysis
This section will focus almost exclusively upon the SR 91 Express Lanes project since it is the only one operational. The appraisal of each of the project categories follows:

- Market Conditions: the traffic demand along SR 91 was well-established; the only unknown was how many travellers would opt to use the HOT lanes over the existing free lanes. This segment of the highway runs through a valley, so SR 91 was currently the most efficient means for getting north or south. Thus, the topography of the region itself supports a lack of competition. These conditions push the locus of the project slightly right.

- Socio-Environmental Conditions: technically, this was a greenfield project, although it utilized space in an already developed area. The scale of the project was moderate while the demographic impact was diverse. Moreover, the availability of a free alternative lessens, if not eliminates, any social inequity arguments. The user fees established would clearly reflect the ‘cost of service’ since the developer would set them at a minimally acceptable rate. Moreover, HOT lanes provide a market for users to determine how valuable their time is. These conditions do not push the locus one way or another.

- Acquisition & Procurement: the competition held amongst all of the projects was really over the expected transportation service that would result. The state had no idea of the “value” it was receiving since comparable proposals or a state-generated benchmark were not part of the process. CalTrans did publish its evaluation criteria, but as mentioned previously these criteria had to be quite general and subjective since CalTrans had little idea about what types of projects it ultimately consider. These circumstances move the locus right and up.

- Concession Management: generally, the issues or conditions related to renegotiation, termination, and facility return were not addressed by CalTrans. These conditions work in favour of the private developer since they are left for interpretation and negotiation. Risks were borne entirely by the developer, and through some rather deft design and planning, the developer eliminated or mitigated some of the most pronounced risks – right-of-way acquisition, environmental permitting, etc. The strict no-compete provision that the developer negotiated worked substantially to its advantage; so much so, that OCTA eventually had to buy-out the developer rather than challenge this condition. These circumstances move the locus right and up.

- Project Performance: in many respects, the SR 91 Express Lanes project was a success. It improved the quality of service, introduced a time/cost choice to the

> traveller, and delivered this service in a timely manner. A major issue, though, is whether the price was right. This concern was mitigated somewhat by the market forces that would drive tolls charged and the cap on the rate of return instituted by the state. Still, competing proposals over this scope of work could have assured the state and its citizens that it was receiving the best value that industry and the market could provide. Moreover, Lessard and Miller (2000) and Guash (2004) have demonstrated that the market or revenue risk is most pronounced in the early stages of these sorts of infrastructure projects. Thus, a more amenable strategy for the no-compete provision might have been adopted. Perhaps, a short-term (5–10 years) provision would have been sufficient to mitigate the revenue risk for the private sponsor, which might have kept a significant constraint from developing for OCTA.

The performance of the other three projects weakens this P3 Programme and lessens the credibility of this particular strategy. SAVE never proceeded beyond the conceptual design stage; its franchise was terminated in 2001. The Mid-State Tollway encountered substantial political opposition once design development and right-of-way acquisition began; its franchise was also terminated in 2001. SR 125 is under construction, but it is over budget and behind schedule. Thus, 16 years after award of the franchise, this project's service is still not available.

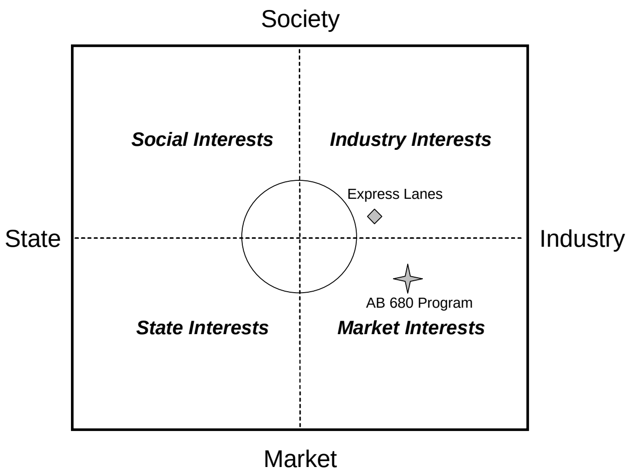


Figure 2: AB680 programme & express lanes project

Summary

The AB 680 Programme and its projects were well intentioned; however, this analysis suggests that a predominant bias toward market interests and a secondary bias toward industry interests at the programme level and vice versa at the project level caused its failure. Clearly, this is a hindsight analysis, but if the framework and templates proposed had been available, then perhaps they may have steered the initiative in a different direction, one that may have had a greater chance of success. Figure 2 illustrates the locus of the overall programme and the location of the SR 91 project.

CONCLUSION

The transition to a world where the propensity of infrastructure services is provided by the private sector appears to be underway. Essentially, governments will become the overseers of service rather than the service providers. Will this transition be beneficial? This endeavour seeks to answer this question by evaluating the effectiveness of P3 programmes and projects in the United States. An equilibrium framework and accompanying analytical templates will be applied to a longitudinal set of case studies. As the research progresses, an answer to the effectiveness question shall emerge, but perhaps more importantly, so shall lessons regarding the keys to P3 success for all the stakeholders involved and impacted by these initiatives. Early results of the research indicate that the contemporary P3 movement in US still has a lot to learn regarding these arrangements. A sub-optimal outcome, however, is not fixed; moreover, the P3 framework, in theory, can encourage both sectors to play to their strengths, the public as policymaker and standard-bearer and the private as innovator and efficiency-expert. The means to this end depends upon balancing the interests of the state, society, industry and the market.

ACKNOWLEDGEMENTS

The insights and feedback provided by Dr Michael C. Vorster of Virginia Tech regarding the P3 Equilibrium Framework are gratefully acknowledged. In addition, this work is funded by grant CMMI-0629260 from the National Science Foundation, whose support is gratefully acknowledged. Any opinions, findings, conclusions or recommendations expressed in this paper are those of the writer and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

Akintoye, A, Hardcastle, C, Beck, M, Chinyio, E and Asenova, D (2003) Achieving best value in private finance initiative project procurement. *Construction Management and Economics*, **21**(July), 461–70.

Bing, L, Akintoye, A, Edwards, P and Hardcastle, C (2005) Critical success factors for PPP/PFI projects in the UK construction industry. *Construction Management and Economics*, **23**(5), 459–71.

Chua, D K H, Kog, Y C and Loh, P K (1999) Critical Success Factors for Different Project Objectives. *Journal of Construction Engineering and Management*, **125**(3), 142–50.

Department of Treasury & Finance (2000) *Partnerships Victoria*, Victoria, Australia.

Department of Treasury & Finance (2003) *Contract Management Policy*, Victoria, Australia.

Economist Intelligence Unit and Andersen Consulting (1999) *Vision 2010: Forging Tomorrow's Public-Private Partnerships*. New York.

Esty, B C (1999) Improved Techniques for Valuing Large-Scale Projects. *Journal of Project Finance*, 5(1), 9–25.

Florian, M (2006) Statement of Mr. Florian, Managing Director, Goldman, Sachs & Co. *Testimony before the Subcommittee on Highways, Transit and Pipelines of the US House Transportation and Infrastructure Committee*, 24 May, Washington, DC.

Froud, J (2003) The Private Finance Initiative: risk, uncertainty, and the state. *Accounting, Organizations and Society*, **28**(5), 567–89.

Garvin, M J (2003) Role of Project Delivery Systems in Infrastructure Improvement. *In:* K R Molenaar and P S Chinowsky (Eds.) *Proceedings of the Construction Research Congress*, 19–21 March, Honolulu, HI, ASCE.

Garvin, M J and Chiara, N (2006) Competencies to Facilitate Public-Private Partnerships. *In:* A Songer, P Chinowsky and P Carillo (Eds.) *Proceedings of the 2nd Specialty Conference on Leadership & Management in Construction*, 4–6 May, ASCE/CIB Grand Bahama Island, Bahamas, 200–7.

Gribbin, D J (2006) Understanding Contemporary Public-Private Highway Transactions: The Future of Infrastructure Finance, *Testimony before the Subcommittee on Highways, Transit, and Pipelines of the US House Transportation and Infrastructure Committee*, 24 May, Washington, DC.

Guash, J L (2004) Granting and Renegotiating Infrastructure Concessions, Doing It Right, *Paper No. 28816*, WBI Development Studies, The World Bank, Washington, DC.

HM Treasury (2007) Available online: http://www.hm-treasury.gov.uk/documents/public_private_partnerships/ppp_pfi_stats.cfm (accessed 1 March 2007).

HM Treasury, the United Kingdom (2004) *Value for Money Assessment Guidance*. London.

Industry Canada (2003) *The Public Sector Comparator: A Canadian Best Practices Guide*. Ottawa, Ontario.

International Monetary Fund. (2004) *Public-Private Partnerships*, Washington, DC.

Kingsley, G and O'Neil, D (2004) Performance Measurement in Public-Private Partnerships: Learning from Praxis, Constructing a Conceptual Model. *In: Proceedings of the 65th National Conference*, American Society for Public Administration, Portland, OR, 27–30 March.

Lessard, D and Miller, R (2000) Mapping and Facing the Landscape of Risk. *In:* R Miller and D Lessard (Eds.) *The Strategic Management of Large Engineering Projects*. Cambridge, MA: MIT Press.

Linder, S H and Vaillancourt Rosenau, P (2000) Mapping the Terrain of Public-Private Policy Partnership. *In:* P Vaillancourt Rosenau (Ed.) *Public-Private Policy Partnerships*. Cambridge, MA: MIT Press.

Loosemore, M and Ng, A (2007) Risk allocation in the private provision of infrastructure. *International Journal of Project Management*, **25**(1), 66–76.

Miller, J B (2000) *Principles of Public and Private Infrastructure Delivery*. Boston: Kluwer Academic Publishers.

Miller, J B (2002) *Case Studies in Infrastructure Delivery*. Boston: Kluwer Academic Publishers.

Orr, R (2006) The Privatization Paradigm. Jumping onto the infrastructure bandwagon. *Infrastructure Journal*, Sept/Oct. Available online: www.ijonline.com

Poole, R W (1988) *Private Tollways: Resolving Gridlock in Southern California*, Policy Insight No. 111, The Reason Foundation, Los Angeles.

Quiggin, J (2005) Public-Private Partnerships: Options for Improved Risk Allocation. *The Australian Economic Review*, **38**(4), 445–50.

Russell, A D and Nelms, C (2006) The public sector comparator: uses and abuses. *In:* R Pietroforte, E De Angelis and F Polverino (Eds.) *Proceedings of CIB Joint International Symposium on Construction in the 21st Century: Local & Global Challenges*, 18–20 October, Rome, Napoli, Edizioni Scientifiche Italiane.

State Government of Victoria (2007). Available online: http://www.partnerships.vic.gov.au/CA25708500035EB6/0/B2FD4F20E80A14B4CA2570AE00050F22?OpenDocument (accessed 1 March 2007).

Industry Canada (2003) *The Public Sector Comparator: A Canadian Best Practices Guide*. Ottawa, Ontario.

US Federal Highway Administration (FHWA) (2007) Available online: http://www.fhwa.dot.gov/ppp/legislation.htm (accessed 1 March 2007).

Yin, R. K. (1994). Case Study Research: Design & Methods, 2nd ed., Thousand Oaks, CA, Sage Publications.

TOWARD A CLIENT-DRIVEN REQUIREMENT MANAGEMENT FRAMEWORK FOR ACHIEVING BEST VALUE FOR MONEY

Daniel Forgues,[1] Lauri Koskela[2] and Albert Lejeune[3]

[1] *Ecole de technologie superieure, 1100 Notre-Dame Ouest, Montreal, Quebec, Canada*
[2] *School of the Built Environment, University of Salford, Salford, Greater Manchester, UK*
[3] *Department of Technology Management, UQAM, Montreal, Quebec, Canada*

Studies have demonstrated the relationship between project failure and poor requirement management. However, there is almost no research in the construction industry about developing clients' capabilities to manage their requirements. The research objective is to propose a systematic planning, management and tracking of client requirements to improve the efficiency of the project team and construction suppliers' ability to generate best value for money. A constructive approach based on three case studies is used to develop and test a client-driven integrated requirement management framework. Such a framework could drastically leverage project contributions to business strategy using far fewer resources, while reducing cost and schedule.

Keywords: client, design management, green buildings, information management, project management.

INTRODUCTION

In the much-heralded Latham Report (1994), value for money (VfM) was placed first in a list of eight client wishes: many clients remain dissatisfied with the VfM they receive from the construction industry. However, as Green (1996) noticed, the industry did not capture the essence of VfM; it only retained the cost reduction aspect of it, leaving aside the much more important aspect of client/users satisfaction. The British government has nonetheless adopted VfM as its policy, and has supported numerous initiatives that strive to change its procurement and project management practices. Key to these efforts is a change of focus in the definition of project and programme requirements from capital costs to fit for purpose and whole life cycle costs.

The most successful of these initiatives are built around Sir Egan's (1998) five key targets: committed leadership, customer focus, integrated teams, quality driven agenda, and commitment to people. They draw from the automotive industry and project management best practices to change the construction paradigm by encouraging process integration and measure of performance, thus promoting continuous improvement in delivering value. However, the processes adopted for paradigm change proved to be expensive and not as successful as expected. It is argued here that these initiatives failed to address management and cognitive issues. The management issue is about building purpose: a building is more than an end product; it is a means to achieve a business objective. VfM, from this perspective, is

[1] daniel.forgues@etsmtl.ca

therefore not only about getting the best value from the project delivery process; it is also about maximizing the project outcomes for better services or business performance. The cognitive issue is about understanding the characteristics and purpose of the different activity systems in the process of defining and managing the expected project outcome with a minimum of waste.

This constructive research study aims to address the VfM management issue using a client-driven requirement management (RM) framework. It builds on the hypothesis that integration, alignment and balance of the management needs arising from the transformation, flow and value generation views for achieving VfM (Koskela 2000). The planning and design of a sustainable development demonstration project involving multiple stakeholders was used to experiment with a RM framework derived from system engineering and strategic management. The research preliminary findings are a first step to provide new empirical evidence on a unique case study where the building project purpose is the keystone of a business transformation programme.

MEASURING VALUE THOUGH REQUIREMENTS

The concept of VfM is explored using two perspectives: authors in Lean construction define value as the fulfilment of client requirements while minimizing the production of waste. Authors in IT and in project management associate Value with the ability to align projects and programmes with strategy (Henderson and Venkatraman 1999; Pmi 2003).

Whereas there is a consensus on the importance of capturing and managing client requirements, not much research has been done to explore how to define and manage clients' requirements within complex projects or programmes. An emerging view is that a programme is a set of projects and actions purposefully grouped to complete a transformation process, and, thereby, realize strategic benefits. Only fairly recently have programmes, such as OGC's (1999) "Achieving Excellence", conveyed the view that construction projects' outcomes could be one of the means of realizing strategic benefits. However, there are two key issues with today's industry practices in handling requirements that have to be resolved. One is the supplier's (professionals and contractors) understanding of the nature of the client (Bertelsen and Emmitt 2005); the second is about defining and delivering the best solution with a minimum of waste (Koskela 2000).

Defining client requirements demands a good understanding of what the client wants and why he wants it. It is common practice that the design team is responsible for establishing client and technical requirements. The issue in complex projects or programmes is that the "client" is a coalition of various stakeholders grouped together to achieve a specific business purpose. One of the key obstacles to the achievement of VfM is the need to cater for this range of stakeholders, each of whom may well have a different interpretation of what constitutes "good value" (Treasury 1994). Moreover, research demonstrates that there is no recognized process on how client requirements should be formalized within the brief: they are often established without the participation of key stakeholders, or lost or misinterpreted. Green and Simister (1999) and Barret and Stanley (1999) point out that identification of the client's needs and business opportunities through the briefing depends less on the ability to conceive design solutions, but more on the capacity to understand the nature of the client and to help him make strategic decisions, especially in complex projects and programmes, when multiple stakeholders are involved. Projects have to satisfy the differing requirements of several parties; the process of achieving a consensus cannot be taken for granted. Requirements have not only to be managed within the coalition that constitutes the team of client representatives and suppliers who have the responsibility to deliver the building, but also within the client organization.

The second issue is about the construction production process. According to the TFV theory, the Transformation (T) view is the one that prevails in construction and in project management: the process is concerned with breaking down the proposed solution into a hierarchy of work elements that are organized in time. However, two more views have to be managed concurrently in order to achieve VfM: the Flow (F) view, which looks at how material and information is efficiently managed through time and space: it is concerned with eliminating waste and reducing the time waiting of information, and; the Value (V) view which is concerned with the fit between client, design requirement and the end product.

The problem managing the F and V views is two-fold: the traditional sequential design process, in which the focus on functional and technical requirements tends to overshadow client requirements, (Kamara *et al*. (2002); and the adversarial business context created by traditional contracting methods, which discourage collaboration between contract parties to define the solution that will best fit the business purpose (Koskela *et al*. 2006). Consequently, the building sector suffers from poor or incomplete scope definition, and frequently experiences considerable changes that result in significant cost and schedule overruns (Hamilton *et al*. 1996). Transactional contracting implies that the contractor's responsibility is limited to achieving the deliverable: at the given date; according to the solution prescribed by the bidding documents; and without interference from the owner during the process. This means great contractor independence, and thus aversion to collaboration. It also means that requirements are presented in a prescriptive way, eliminating opportunities for proposing creative solutions to problems.

Reports and studies suggest that the use of Integrated Teams and relational forms of contracting should overcome these issues, and improve value generation through a collaborative, multidisciplinary approach to managing requirements. The success of initiatives such as the UK Department of Health Procure-21 seems to confirm this assertion. Integrated teams, nonetheless, face new challenges in managing the complexity of handling the multiple layers of client and technical requirements concurrently. Methods and tools have been developed in other disciplines or industries to handle complex, evolving requirements effectively. The research aims at testing a client-driven RM preliminary construct developed in previous research.

A CONSTRUCTIVE RESEARCH APPROACH TO VFM

Constructive research treats practice as a fundamental category for making constructs as well as in ensuing theorizing (Lukka 2000). Researchers adopt two roles in the constructive research process: an inquiry role, in which the researcher should be able to view the activity systems from a systemic perspective, and create models or constructs about the activity systems as if they were looking at them from above; in the intensive stage of the study, the researcher's attention switches to the change process and, there, primarily to the individuals' and the organization's problem and solution processes.

The process of constructive research is complex and non-linear. It requires understanding and interpreting the real world; it also necessitates creating and experimenting with models of a new reality. The idea of a client-driven RM approach as a means of aligning project results with strategy emerged from prior research on enhancing construction project delivery processes. Systematic RM is the process of capturing the documented statement of stakeholders' and users' wants and needs (quality), and ensuring that the solution efficiently meets these requirements (conformance). The systematic management of Requirement processes is identified as a project key success factor in system and software engineering literature.

The research was designed as a series of steps or iterations, moving from literature to interviews and case studies, in which models are used at each step as mediating artefacts when interpreting and acting on the real world (Figure 1). This paper presents part of the results of the third iteration.

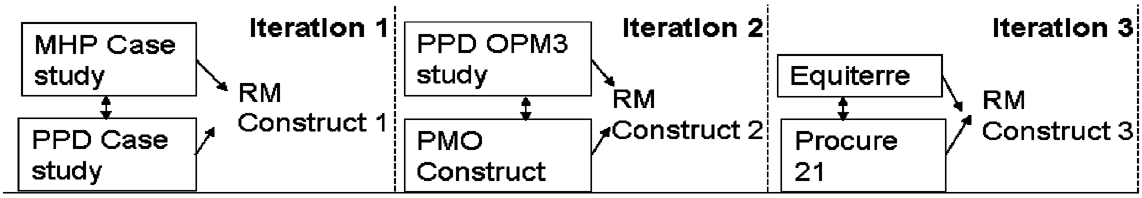


Figure 1: Constructive research iterations

The first iteration was conducted within the Canadian Services construction programme, which was experiencing serious problems dealing with complex evolving multiple client requirements. A weapon development programme using leading-edge RM processes was used as a case study to develop an RM concept of operations. The second iteration (Figure 1) explored the multiple levels of requirements of complex projects and programmes based on the Project Management Organizational Project Maturity Model (PMI 2004).

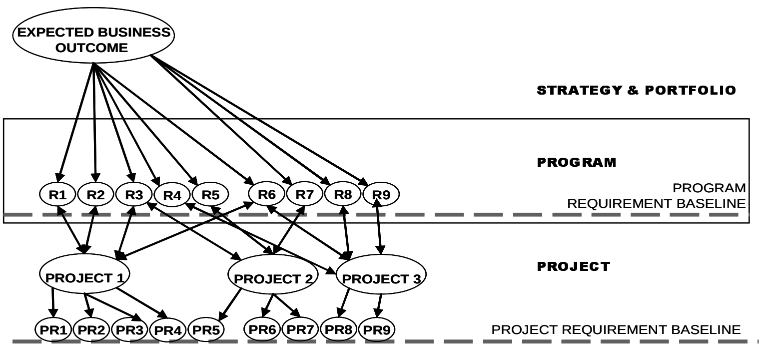


Figure 2: Programme requirement-based construct

This model contends that project outcomes should be aligned with strategy through portfolios, programmes and projects. Figure 2 proposes a systematic approach to provide this dynamic alignment from the strategy (providing the outcomes related to the business objectives) to operations (providing the building expected characteristics) through layers of requirements. Kauppinen (2005) identifies three levels of requirements: business requirements – high-level objectives of the organization or customer; user requirements – describe user goals or tasks that the users must be able to perform with the product; and technical requirements – more detailed descriptions of the user requirements, are defined from the point of view of the expert. Sommerville (2004) points out that some of the key problems in managing requirements result from a failure to make a clear separation between the different levels of requirements. Strategic alignment was identified as a possible answer to the issue of managing different layers of requirements in the organization, from the strategy (providing the outcomes related to the business objectives) to operations (providing the building expected characteristics).

The aim of the construct was to provide real-time dynamic alignment capability to manage a complex construction programme. In this model, the programme requirement baseline is the mediator between strategic and project requirements. Deviation from the baseline induces three possible courses of actions: at the project level, taking corrective actions; at a programme level, adjusting the programme strategy in delivering the expected benefits, or; at the business strategy and portfolio levels, adjusting the strategy according to emerging strategies from the program and the project context.

RESEARCH METHODS

Two other case studies – in which Integrated Design Process (a multidisciplinary approach to problem-solving having its roots in concurrent engineering, where it is combined with parallel task processing to reduce cost and delays in design and production while increasing the process quality. By encouraging collaboration, IDP addresses numerous problems associated with the management of Flow (F) and Value (V) in sequential design, such as briefing process disclosure and feedbacks (V) problems, or design process resolution of wicked (F) problems) or relational contracting were used to encourage collaboration – were identified to develop and test the construct: the first as a reciprocal case (Yin 2003), the second as an instrumental case study. The paper presents the preliminary results of the latter, an on-going green building demonstration project in Canada. The case study process was divided into two phases: The first phase – the Constructive Research inquiry stage – focused on the observation of the client and design team interactions; the second phase, on the construct experiment for the management of requirements regarding sustainability.

The inquiry stage aimed at understanding the management and cognitive issues related to integrated design and defining the best strategy to test the RM construct. A total of five brainstorming and four design workshops were observed in École de Technologie Supérieure e-collaborative design tools laboratory. The workshops were filmed, and all electronic documents and drawings recorded. A qualitative, grounded research interview-based case study was carried out to identify the client stakeholders' wants and expectations. Nine interviews were conducted, five with the shareholders and four with the stakeholders, to establish the shareholders' business objectives and the stakeholders' needs, expectations and. requirements regarding sustainability. The resulting data were analysed using Nvivo7 software, and prioritized in Doors client requirement module of the Doors data model (Figure 3).

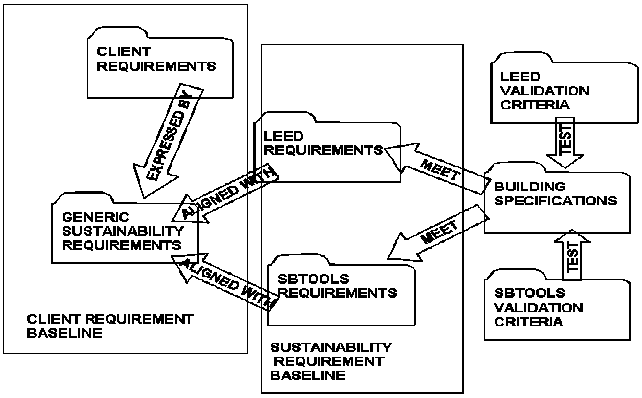


Figure 3: Doors data model

The model is the instantiation of the RM construct (Figure 1). The client requirement module (strategy) contains the sustainability business requirements, which are detailed in the generic sustainable requirement module. Generic requirements cover the programme's social, economic and environmental perspectives. They constitute the client's programme requirement baseline. The building requirements (LEED and SBTools) are the project sustainability technical baseline.

The intensive stage of the study aims at testing the use of systematic RM to manage the client's strategic and operational requirements. A preliminary RM modelling was realized to map the tracking process of the sustainability requirements. Two environmental benchmarking tools were selected to demonstrate the project's sustainable value: The Leadership in Energy and Environmental Design (LEED) Green Building Rating System™, the most popular rating system for the design, construction, and operation of high performance green buildings in North America, and SBTool 07, benchmarking software developed as part of the Green Building Challenge process, an international effort to establish a common language for describing "green buildings". Finally, a LEED/SBTool baseline was created to verify proposed design solutions against LEED/SBTool sustainability requirements, and to validate these solutions against client sustainability requirements.

CASE STUDY DESCRIPTION

Maison du développement durable

The Maison du développement durable project aims at building a sustainable building demonstration project in downtown Montreal. The client, Equiterre, is a non-profit organization devoted to promoting social equity and a more sustainable world. Equiterre has built its reputation on programmes that are now a few years old. Its board felt that Equiterre had to redefine itself to deliver a more powerful message. Equiterre's strategic objectives are to leverage the organization influence in sustainable development by creating a pole of attraction, a model of what sustainable development should be; and to consolidate the organization and its partners. To do so, Equiterre has created a coalition with eight other non-profit organization sharing similar values; these will be the partners and the tenants of the project. It has also devised a new sustainability programme, of which the demonstration project is the keystone.

Competition for public and private funding is fierce. The project aims to be a strong public statement and a platform to launch new programmes. It will also help to recruit public and private partners. As a demonstration project, it will attract visitors (and future members). It is totally funded through grants.

Equiterre has no experience in construction projects. However, it has formed a steering committee represented by executives and experts from large real estate organizations. The design team was selected through a multiple stage process based on the following criteria: working chemistry among the team and with Equiterre's project team; quality of their projects, experience in sustainable construction; and shared values with Equiterre. The team has realized the first certified LEED Gold project in the Quebec province, and has won numerous prizes. According to the contractual arrangements, the team had to use an integrated design process to achieve LEED/SBTool sustainability requirements. The aim is to receive international recognition by exceeding the most stringent certification requirements. The team also has to conduct workshops in Ecole de technologie superieure laboratory as part of the research programme.

The integrated design management process

IDP is an iterative approach originating from product and software development, designed to aggressively reduce uncertainties, in favour of earlier and better decision-making. It was successfully used in system engineering to drastically shorten the development time of software intensive advanced weapon systems, such as spy planes (U2 and SR71A) or satellites. Various formal or agile integrated design frameworks are now used in these industries.

RM plays a central role in these fields. Problems in handling requirements account for close to 60% of project failures (Standish Group 1994). Stage-gating, configuration management and requirement engineering methods and tools are considered as essential for developing the necessary capabilities for achieving required project performance. They are core requirements in achieving higher maturity levels in the Software Capability Maturity Model. It has proved in software development to drastically reduce waste, while providing a much better fit for purpose.

Integrated design is just emerging in construction, and there is no clear definition or framework for applying it. It has been identified as the best approach for delivering VfM, and it is also acknowledged as the best approach for delivering sustainable buildings. These two main strands – one driven by the Rethinking Construction movement, the other by the sustainability movement – are both aimed at increasing the industry's capability to deliver a better product with a minimum of waste. The first movement is client-driven; the second is supplier-driven. The Equiterre project is in the second category.

Testing the RM framework

The construction industry's aversion to innovation is well known. Testing an RM framework in an integrated design context is far-removed from traditional practice both on the client and supplier's sides. Alignment is not a concept commonly used in organizations that regard the management of real estate project portfolios. Alignment models are scarce, and belong to other disciplines. Moreover, critics of strategic planning and alignment maintain that the implicit dominance of a structured strategy process is questionable in an era when uncertainty and flexibility predominate. Ciborra (1997) argues that management, through knowledge and understanding of alignment, can classify their strategy in terms of boxes and linear relationships, but back in the real world, they have difficulty measuring those relationships or formulating processes to apply the alignment maps in practice. In other words, conventional theory on alignment does not address cognitive issues. The testing plan was built around "soft" approaches to IT system implementation to mitigate these issues (Table 1).

Table 1: Key ingredients in the testing learning cycle (Walton 1989; Ciborra 1997)

Walton	Ciborra
Alignment: • Vision aligned with business, organization, and technology strategies • System design and operational use aligned with vision	Alignment: • Grounded approach to alignment: understanding the business phenomena to enrich the geometric notion of alignment
Ownership: • Organizational commitment (sponsorship); stakeholder support for IT • System designed to tap and promote user ownership • Users feel strong ownership of the system	Care: • Familiarity, intimacy and continuous commitment by the various actors involved in the design, implementation and use of the system Hospitality: • New technology is highly ambiguous. Acceptance has to face ambiguity: coping becomes hospitality
Competence/Mastery: • Competence and IT literacy • System designed to use and promote mastery • Users mastering the system	Cultivation: • Is based on frequent misalignment and misfit: the technology being accumulated is greater or different in its potential, than current internal or external needs

Equiterre has set a steering committee at the programme level and a technical advisory committee at the project level. The inquiry stage was divided into two: observation of the supplier-driven process and observation of the steering committee handling of the programme. The supplier design process was staged in a series of one day and half a day Workshops, held from August 2006 to February 2007. The intensive stage of experiment was started in parallel with the inquiry stage. A qualitative grounded research technique was used for Requirements elicitation and analysis at the programme level. A Programme Charter, which outlined the programme strategy objectives, was derived from this analysis. The sustainability related objectives were broken down into characteristics. Both Charter and characteristics were mapped into Doors using the traceability links and then frozen into the client requirements configuration baseline. The LEED and SBTools benchmarks were then mapped and each criterion linked to a client configuration item. They constitute the project technical baseline. The proposed concept is now being assessed against these two baselines.

DISCUSSION

The case study had a unique feature that enabled the parallel inquiry and intensive stages. Two sustainability benchmarks were identified to obtain international recognition. However, neither the client nor the design team realized that the benchmarks were built around opposite design strategies. In contrast to SBTools, LEED does not demand any change in the traditional Sequential Design process (T view). It is essentially a checklist. The objective is to gather as many sustainability points as possible. The trend in the industry is to develop the design, conduct the energy simulation, and add technology to increase energy efficiency up to the desired score. There is no specification about if integrated design should be used, and how it should be managed. The design team was familiar with LEED and devised a series of workshops to meet the client's requirement for an integrated approach.

The brief prepared by the architect captured the space requirements, but not the business strategy and objectives, nor the constraints imposed by the project financing scheme. After one year of work, the concept was assessed against the programme expected characteristics and the project technical baseline. Whilst achieving most of the LEED sustainability criteria, the scheme did not achieve some core business objectives, and exceeded the cost targets. Management and cognitive issues were observed during the inquiry stage, with the conducting of workshops, which were also perceived by the client as quite ineffective and time consuming.

One management issue is the complexity of handling multiple levels of requirements. Because there was no organized process for managing the hierarchy of requirements, discussions moved from technical to business requirements and vice-versa: time was wasted in useless iterations between these two levels. A cognitive issue was the experts' difficulty in understanding what kind of information the client needed for decision-making. The experts pushed the client to make decisions to develop the design options, while the client was asking cost information to asses their business value. This is qualified as cognitive inertia and compartmentalization. One of the mechanisms behind such inertia is "groupthink", a mode of thinking that people engage in "when they are deeply involved in a cohesive in-group." "Groupthink" typically leads to an overestimation of the in-group, closed-mindedness and stereotypes of out-groups. Another possible mechanism is, paradoxically, almost the opposite of "groupthink", namely, fragmentation of viewpoints and lack of "shared mental models." Such fragmentation may make it impossible for experts from different contexts to "speak the same language" and exchange ideas about a problem.

The advantage to conducting the inquiry and intensive stage as two parallel processes was to make the client realize the value of a client-driven RM approach. SBTools shares System Engineering RM Vee model core principles of decomposition and abstraction: it was used as the sustainability technical requirement framework and integrated in Doors programme-based construct. The system is partitioned into finer and finer elements, while the requirements start at a highly abstract level to become more specific for the lower-level elements. SBTools first requires that sustainability targets be identified by the client at the beginning of projects (V). A reference model is developed by a third party to define the local benchmarks regarding common, good and best practices. A concept is generated through workshops and tested against the reference model. The client, after reviewing the score of the concept against the reference model, can then adjust his target. Then a series of steps are defined to refine the design for each component through design workshops. The result from iteration is adjusted against its related benchmark (T & V).

CONCLUSIONS

It is reported in this paper that preliminary research results from an instrumental case study aimed at providing a proof of concept for the programme-based RM alignment construct. They demonstrated the value of using client-driven RM to achieve VfM. The client was capable of comparing the proposed concept with his requirement baseline, and of identifying flaws in the design. They also highlighted the issues related to changing the industry's practices. Researchers have advocated that VfM is best achieved through integrated approaches and relational contracting, but did not address the management and cognitive issues related to these approaches.

This research is exploratory and still ongoing. The exploratory systematic RM construct will have to be experimented on in the second phase of the project. A reciprocal case study has been conducted in parallel, and a conceptual framework was developed to explore the socio-technical aspects of VfM. The intensive stage will be used to validate, better understand and extend this framework. Questions about the cognitive issues and their articulation against TFV theory will be further investigated.

REFERENCES

Barrett, P and Stanley, C (1999) *Better construction briefing*. Oxford: Blackwell Science Ltd.

Bertelsen, S and Emmitt, S (2005) The client as a complex system. *In:* A H Boussabaine, R J Kirkham and G E M Jared (Ed.) *1st International Conference on Complexity and the Built Environment*, becon 2005, University of Liverpool, 117–26.

Ciborra, C (1997) De profundis? Deconstructing the concept of strategic alignment. *In: IRIS conference*.

Egan, J (1998) *Rethinking construction: The report of the construction task force*. London: DETR.

Green, S D (1996) *Smart value management: A group decision support methodology for building design*.

Green, S D and Simister, S J (1999) Modelling client business processes as an aid to strategic briefing. *Construction Management and Economics*, **17**, 63–76.

Hamilton, M R and Gibson, G E J *et al*. (1996) Benchmarking preproject planning effort. *Journal of Management in Engineering*, 25–33.

Henderson, J C and Venkatraman, N (1999) Strategic alignment: Leveraging information technology for transforming organizations. *IBM Systems Journal*, **38**(2), 472.

Kamara, J M, Anumba, C J and Evbuornwan (2002) *Capturing client requirements in construction projects*. Cornwall: Thomas Telford Publishing.

Kauppinen, M (2005) *Introducing requirements engineering into product development: Towards systematic user requirements definition*. Helsinki University of Technology

Koskela, L (2000) *An exploration towards a production theory and its application to construction.* Finland: Technical Research Centre of Finland.

Koskela, L, Howell, G and Lichtig, W (2006) Contracts and production. In: *CIBW92*, Salford.

Latham, S M (1994) *Constructing the team*. London: HMSO.

Lukka, K (2000) *The key issues of applying the constructive approach to field research*, Sarja: Turku School of Economics and Business Administration.

OGC (cited 2006) Achieving excellence in construction. Available online: http://www.ogc.gov.uk/index.asp?id=218

PMI, P M I (2003) *Organisational project management maturity model*. Newton Square, PA: PMI.

PMI (2004) *The guide to the project management body of knowledge*. Newton Square, PA: PMI.

Sommerville, I (2004) *Software engineering*. 7ed. Boston, MA: Pearson/Addison-Wesley.

Standish Group (1994) *The chaos report*.

Treasury, HM (1994) *Project sponsorship, cup guidance note no. 33 (rev).* London: HM Treasury, Central Unit on Procurement.

Walton, R E (1989) *Up and running integrating information technology and the organization*. Boston, MA: Harvard Business School Press.

Yin, R K (2003) *Case study research - design and methods*. Vol. 5. London: International Educational and Professional Publisher.

RISK, VALUE, UNCERTAINTY AND REQUIREMENTS MANAGEMENT IN PROJECTS

Nigel Smith[1] and Steven Male

School of Civil Engineering, University of Leeds, Woodhouse Lane, Leeds, WF2 6SQ

Although much discussed and researched over the years, the difficulty of making effective decisions early in the project appraisal stage remains an issue. Preference and practice still play almost as important a part as data capture and methodology. Business and project process improvements in the industry are addressed, placing the client and the development of project strategy and its subsequent implementation at the forefront of those improvements. A framework to facilitate understanding management of the early stages of a project is proposed based upon the four major themes of the title: risk, value, uncertainty and requirements management. The paper draws on previous studies conducted by the authors and others into the significance of the early stages of a project. The arguments set out seek to demonstrate the feasibility of integrating those themes in the appraisal stage of projects, and potentially for later stages in the project life cycle, with a view to determining the best practice framework and methodology for undertaking this.

Keywords: appraisal stage of projects, requirements management, risk management, uncertainty management, value management.

INTRODUCTION AND RESEARCH METHOD

In the early stages of projects at a detailed process level extensive empirical studies linked to theoretical work concerning the relationship between the four major themes identified in this paper as a comprehensive package are missing from the research literature. More importantly, there is a dearth of systematic research at the formative stages of projects where early project decisions are made by clients, consultants, bankers and lawyers and, increasingly, by contractors under the newer forms of collaborative procurement (Graham 2001). The paper uses the term ‘strategic project management’ (Grundy and Brown 2002) to describe the overarching activity of setting up the early stages of a project and draws on work dealing with the strategic phase of projects and the project value chain (Bell 1994; Graham 2001; Male and Kelly 1992; Moussa 1999; Gorog and Smith 1999; Latham 1994; Standing 2000; Woodhead 1999).

The impetus for this paper also comes from the authors’ continued work in value and risk management for over nearly two decades. Smith has published widely on risk management (Smith 2002, 2003, 2006), on the integration of risk and value management (Smith and Afila 2007) and in the area of PPP/PFI (Smith and Merna 1996, Smith and Mackie 2005). Since the mid-1980s Male and Kelly have conducted a number of strategic studies in the value management (VM) area, notably for the

[1] n.j.smith@leeds.ac.uk

Royal Institution of Chartered Surveyors and consolidated in Kelly and Male (1993), and work funded by the UK's Engineering and Physical Sciences Research Council where the outcome was an internationally benchmarked best practice methodology for VM (Male *et al*. 1998a, 1998b). From 1998 onwards Male and Kelly, using a combined approach of action research (Bryman 1989; Robson 2002), grounded theory (Glaser and Strauss 1967, Goulding 2002) and reflective practitioner in-action approach (Schon 1991, 1999), subsequently tested for robustness and enhanced further that methodology through conducting in excess of 100 action-research focused industrial studies and systematically analysing the outcomes. That work has been consolidated in Kelly *et al.* (2004) and Male *et al.* (2007) within a historical, current and international analysis of VM and its potential future direction. In sum, the process has involved the interactive effects of research-driven practice and practice-driven research.

THE FORMATIVE STAGES OF PROJECTS

Many clients experience difficulties at the very earliest stages of the construction project life cycle in producing a robust project strategy, not least a 'brief' (Latham 2004). This early stage, defined as the 'appraisal stage', extends from 'inception' to 'sanction' (Simon *et al.* 1997); it can also be extended earlier to include a pre-brief or pre-concept/inception stage with clear relationships to business strategy and investment decisions (Kelly and Male 1993). Consequently, the appraisal stage contains two types of decision making under conditions of uncertainty, namely the viability decision (related to the investment decision as a business project and its correct definition) and the decision on the preferred and most feasible technical option (the appropriate technical project). Both processes require 'strategic fit' and may be completed before the contract and procurement strategy is determined, the project is sanctioned and often before the number of major organizations to be involved has been agreed. The appraisal stage is also where requirements need to be carefully thought through and made explicit, where strategic procurement issues need to be considered and also the organization's approach to managing uncertainty becomes important because it is at its highest. It is also the gestation period for value and risk parameters to be established.

Moussa (1999) split the overall project process into two major phases, project definition, covering the appraisal stage discussed here, and project delivery. In the case of the former, Woodhead (1999) undertook an in-depth analysis of the decision to construct process – one located within the appraisal stage – through the study of a range of different types of projects and their formative stages. He uncovered a collection of influences impacting on project definition and designated these influences paradigms and perspectives. The former comprise the rules, expectations, values and codes of practice that are explicitly or implicitly part of professional and other stakeholder groupings playing a part within the decision to construct process. Perspectives are those views existing within any given paradigm. Paradigms and perspectives shape and structure the process of the decision to construct. They also dictate its content. Woodhead also concluded that as the decision to construct progresses through a series of stages, each is impacted on by different decision roles, namely, the formal decision functions of decision approving, taking and shaping, and finally, that of decision influencing.

Although the appraisal stage also encompasses the formal establishing of a project, Graham (2001) indicated clearly the difference between the start of the strategic phase of a project and the start of the project itself. Projects go through a variety of changes within the client organization before they emerged as projects with a clear momentum ready for the construction industry to commence its work (Kelly *et al.* 2004; Woodhead 1999). The strategic phase of the project development process is therefore often 'messy', 'fuzzy' or 'ill-defined' and can be difficult to pin down in terms of a clear start date for a particular project. This adds to uncertainty and risks and also necessitates the management of different and potentially conflicting value systems. This is explored further in the next section.

UNCERTAINTY, VALUE, RISK AND REQUIREMENTS MANAGEMENT IN PROJECTS

Bell (1994), defining value as the intrinsic property to satisfy, notes it has an economic perspective in terms of the ratio of costs to benefits and where the primary mechanism for communication of value decisions is in monetary terms. She added that other authors have presented value in terms of characteristics, namely, use qualities, esteem features linked to ownership; market exchange properties; and cost characteristics. There are perceptual and utility dimensions to it. Bell (1994) also notes that the number of interfaces that exist between individuals, groups of individuals, or organizational units deciding on value also come into play.

Recent research by Smith and An (2006) demonstrates that new perspectives are emerging that are influencing the way risk assessment is viewed, particularly in terms of uncertainty, complexity and opportunity. Risk and uncertainty are key features of the appraisal stage, with risk management no longer concerned only with detrimental factors but with the inclusion of the concept of opportunity means that there is also the possibility of emerging factors that can have a positive impact on the project. Risk management, while not predicting the future, nevertheless provides a better approach in making key decisions (Chapman 1998; HSE 2003). However, in respect of the terminology and semantics of risk management the same terms are used by different industrial sectors in different ways to describe discrete activities that not only occur at different points on the project life cycle but are cyclic or repetitive processes involving different levels of certitude, and possibly different methodologies. There is no surprise that a degree of confusion exists. Nonetheless, risk management is usually defined with key phrases including coordination of activities or application of management policies, procedures, methods and practices to identify, analyse, evaluate, treat, control and monitor risk to minimize adverse effects (IRM 2002; AS/NZ 2004).

There also appear to be very close linkages between conceptual approaches to value and risk management and the ideas and concepts from within the emerging research field of uncertainty management (UM), and, also requirements management (ReqmtM) (Standing 2005). The focus of UM is on making decisions and managing in the face of significant uncertainty (Cooper and Chapman 1987; Chapman 1997; Chapman and Ward 2002; Hetland 2003), defined as a lack of certainty derived from high levels of variability and ambiguity (Chapman and Ward 2002). Chapman and Ward include risk within the definition of UM, as does Hetland (2003); they view it as incorporating upside risk (opportunity) and downside risk (threat). Male and Mitrovic (2005) have recently linked project uncertainty, risk, value and supply chain strategies together with a client typology using Hetland's thinking. Equally, Smith and Afila (2007) have investigated the links between value and risk management; the OGC (2007a) has produced a guide which explores their integration within the Gateway process; while CIRIA (2005), Dallas (2006) and Walker and Greenwood (2002) have explored the linkages between managing risk and value through the use of concepts, ideas, methods and toolboxes of techniques in a similar manner to Male *et al.* (1998a, 1998b).

Finally, requirements management, with its origins and methodologies in information technology, focuses on eliciting, documenting, organizing and tracking requirements, a ‘capability’ that is needed by a user to solve a problem or objective (OGC 2007b). Nomenclature in the requirements management area includes stakeholders and project teams, the ‘voice of the customer’, goals, functions and constraints to product and service specifications, including related systems behaviour. These terms also appear in the VM paradigm. The value and traditional risk paradigms also address the management of complexity, uncertainty and ambiguity through their respective methodologies, and implicitly also opportunity. Figure 1 brings together the key concepts discussed above.

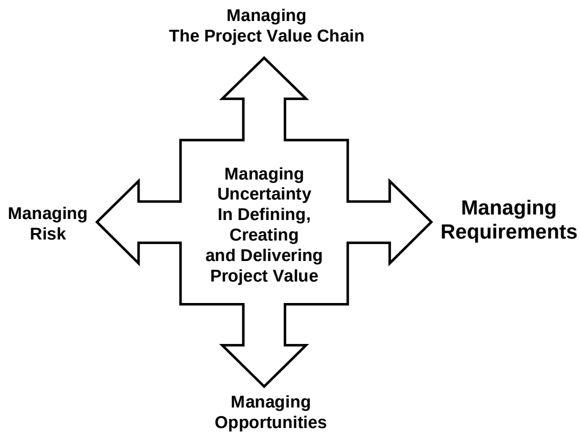


Figure 1: Managing uncertainty in project value (Male and Smith 2007)

The next section explores the above through the presentation of two case studies.

CASE STUDY: A LIBRARY PROJECT

A case study is presented drawing together different insights into the use of value and risk management, reductions to uncertainty, and also requirements management. The study is of a library project where value management/value engineering had been used in a reactive as well as proactive manner at different stages of that project.

The traditional VM paradigm has function analysis at its core (Kelly *et al*. 2004); variations on this technique have also emerged, including the function breakdown structure and objectives hierarchies (Male *et al*. 2007). They have differences in their application; some are more suited to existing products and others to problem definition and new product development. As part of the development process in function diagramming, Kelly *et al*. (2004) describe three function techniques linked to requirements capture. The techniques are the function priority matrix, developed due to a frustration of using FAST diagramming with large teams under collaborative procurement structures; the strategic FAST diagram, which is very useful for diagrammatically representing purpose related to function and the value engineering (VE) functional cluster diagram, relating major elements within buildings to the Royal Institution of Chartered Surveyors BCIS elemental analysis, functions and subsequently cost. In terms of interlinking, the function priority matrix is normally constructed first, then the strategic FAST diagram from constituents of the priority matrix and finally, if a value engineering constituent is required, the VE clustering diagram. Kelly *et al*. (2004) make the point that they are a series of linked function techniques that help structure information and requirements in a logical way within often competing value systems.

The study was conducted at the concept briefing stage, with each of the above techniques used to brief the project. As part of the study and prior to a VM workshop, the study leader and a 'briefing architect' interviewed key personnel in the university to establish their perceptions of the reason for the project, its key use requirements and major functional space requirements. Important constraints were also identified. During successive workshop activity, a series of function analysis techniques were used. The three primary techniques are brought together in Figure 2, together with an example of risk brainstorming using the functional cluster diagram approach where this technique was extended further at a similar stage in an MoD prime contract.

Typically a team will be taken through a structured workshop process, where initially an issues analysis is conducted (Kelly *et al*. 2004) to address uncertainty, risk and value through a joint exploration of information. Purpose analysis, objectives hierarchies and functioning diagramming are then used to take a team back to the basics of why a project exists, and what functions are necessary for the end product as a physical asset to be briefed, constructed and operated. Subsequently through a process of ideas generation and option development options are worked up, value added and risks mitigated; quantitative risk management would take place outside the workshop process. Action planning puts those options into implementation. Depending on the type of study, at this stage options may well fall into: strategic improvements to be addressed by the client; technical design and or construction-related options; project management and project process options and risk mitigation options.

In the case of the library project, the team were taken through the issues analysis and then subsequently into function analysis. First, the function matrix was developed, sorted and prioritized. Second, having established the strategic purpose of the project, spatial adjacency matrices and flow diagrams were used to prioritize space and identify any important spatial function requirements. Third, the VE cluster diagram was used to establish the functional requirements of the end product – the physical asset. Links between each major functional cluster and the BCIS functionally based elemental structure permit alternative technical options to be tied to function and subsequently cost parameters. The value management team appointed independently by the university and comprising client representatives, end users and technically based consultants, including a contractor, established the competing technical alternatives to meet the function while taking account of buildability, life cycle and onsite programme and logistics issues. The final output-based specification was agreed for each major function cluster with clear linkages established to each of the BCIS elemental breakdown structure as the normal cost-planning technique for cost consultants.

The VM team also took a holistic approach to the whole VE cluster diagram to ensure the technical integrity of the outline output specification; the cluster diagram also permits risk brainstorming against each of the elemental groupings. Finally, a cost consultant within the VM team established the appropriate cost/square metre rate for each of the BCIS elements using ideas on the most likely technical alternatives to drive this. This established the budget for the building and element-by-element cost ranges linked to functional requirements, leaving any subsequent designer freedom to choose appropriate technical solutions within specified cost limits. The final stage of the VM workshop process was to determine the appropriate procurement route through options generation. In summary the combined use of the techniques captured the requirements very quickly in the early stages of the project and, as a direct consequence, uncertainty and risk were progressively addressed through the workshop process with the elicitation and capture of requirements. Subsequently, this cascaded into the appropriate choice of procurement route.

CONCLUSIONS

The core of value management as a structured process is to ensure that an investment strategy achieves the desired impact and benefits for an organization. Dallas (2006) notes that a successful project of any type requires that the outcome is clearly defined (requirements) and communicated to those delivering the project (the team). He notes VM addresses this element. Equally, he argues that successful project delivery requires an effective delivery process where the impacts of the ‘unexpected and uncertainties’ are minimized. He contends that this is the role of RM.

This paper has argued that the coming together of RM and VM in theory and in the practice setting, normally around workshop processes, is not without its difficulties but is solvable; they however originate from different theoretical paradigms and have differing underlying philosophies and methodologies. Equally, additional work conducted by Male, Smith and Gronqvist with a large engineering contractor indicates clearly that value creation should be addressed first, by addressing opportunity-based options; second, by investigating the risks associated with those options; and third, by relating those risks additionally to a more general analysis of project risks. The clear implication is that the mental mindsets associated with generating and investigating opportunity-based options is positive, subsequently the workshop process should address the more negative aspects associated with risk analysis and mitigation. It is not uncommon for value management teams to be split into working groups, some focusing on value opportunities and the associated risks; subsequently, other working groups may investigate risks and mitigation measures. Consequently, this approach can move to more quantitative assessments associated with risk management.

The approaches identified in the paper have stemmed from a prolonged period of involvement and observation from action research studies, the purpose of which has been to intervene in organizational processes using research frameworks as well as generate further insights for subsequent research projects. A series of techniques have been presented that address the simultaneous management of uncertainty, value, risk, opportunity and requirements management. Figure 2 comes from within a value and risk framework and focuses on value by addressing opportunities (explicitly), uncertainty (implicitly) and risk (explicitly); neither study used computer software to capture requirements for subsequent management throughout the project life cycle. Software is now generally available, with origins however within the information technology domain, to also elicit and capture requirements, subsequently using that software to track these through different stages of the project.

At the post-project evaluation stage these computer-based software approaches for generating and tracking requirements can be used to audit information and determine if those requirements and subsequent benefits have been delivered. The paper has argued that there is no comprehensive framework that brings together the concepts, methodologies, tools and techniques that exist within the different and potentially complementary themes discussed here. This paper further proposes that a coming together and resolution of these apparently overlapping areas theoretically and empirically can only but strengthen the appraisal stage of projects, arguably the most important domain for impacting subsequently on the rest of the project life cycle.

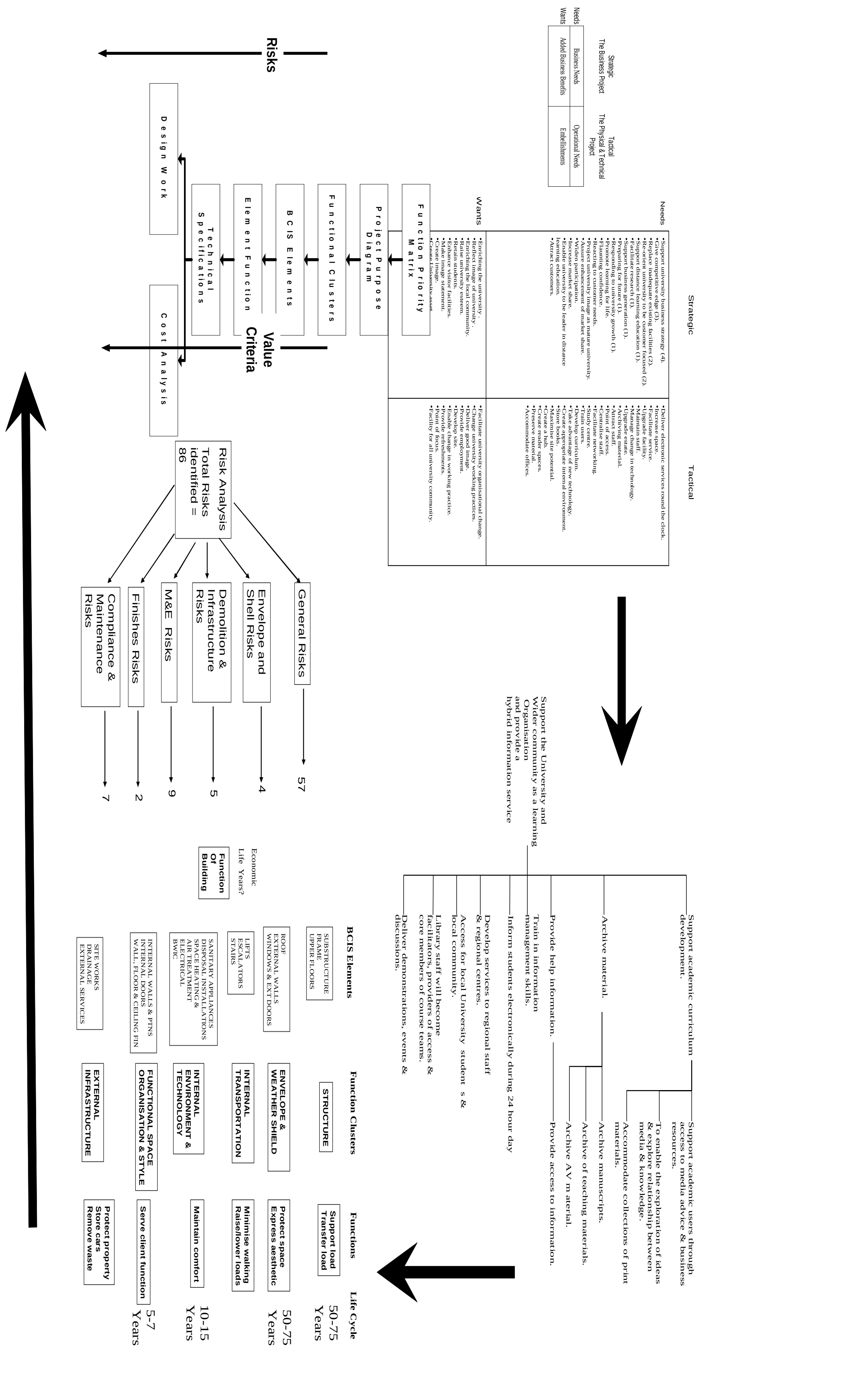


Figure 2: The value requirements and risk capture methodology (adapted from Male 2002; Kelly *et al.* 2004; Gronqvist 2005 and fieldwork)

REFERENCES

AS/NZS (2004) *Risk management.* Australian/New Zealand Standard.

Bell, K (1994) *The strategic management of projects to enhance value for money for BAA plc,* Unpublished PhD Thesis, Department of Building Engineering and Surveying, Heriot Watt University.

Bryman, A (1995) *Research methods and organisation studies.* Reprinted 2002. London: Unwin Hyman Ltd.

Chapman, C B (1997) Project risk analysis and management. *International Journal of Project Management,* **15**(5), 273–81.

Chapman, C B and Ward, S (2002) *Managing project risk and uncertainty.* Chichester: John Wiley & Sons.

Chapman, R J (1998) The effectiveness of working group risk identification and assessment techniques. *International Journal of Project Management*, **16**, 333–43.

Cooper, D F and Chapman, C B (1987) *Risk analysis for large projects: models, methods and cases.* Chichester: John Wiley & Sons.

Dallas, M (2006) *Value and risk management: a guide to best practice.* Oxford: Blackwell Publishing.

Glaser, B and Strauss, A (1967) *The discovery of grounded theory: strategies for qualitative research.* Chicago: Aldine.

Goulding, C (2002) *Grounded theory: a practical guide for management, business and market researchers.* London: Sage Publications.

Gorog, M and Smith, N J (1999) *Project management for managers.* Newton Square: Project Management Institute.

Graham, M (2001) *Project management of infrastructure projects,* Unpublished PhD Thesis, School of Civil Engineering, University of Leeds.

Grundy, T and Brown, L (2002) *Strategic project management: project managing your business strategy.* London: Thomson Learning.

Hetland, P W (2003) Uncertainty management. *In*: N J Smith (Ed.) *Appraisal, risk and uncertainty*. London: Thomas Telford.

HSE (2003) *Causal factors in construction accidents.* Health and Safety Executive (HSE). HSE Books: Research Report 156. Suffolk: Sudbury.

IRM (2002) *A risk management standard*. London: The Institute of Risk Management.

Kelly, J R and Male, S P (1993) *Value management in design and construction.* London: E & FN Spon.

Kelly, J R, Male, S P and Graham, D (2004) *Value management of construction projects.* Oxford: Blackwell Science.

Latham, M (1994) *Constructing the Team*, Final Report of the Review of the Procurement and Contractual Arrangements in the UK Construction Industry. London: HMSO.

Male, S P and Kelly, J R (1992) Value management as a strategic management tool. *In*: *Value and the client, Proceedings of ICC Seminar*, 29 January 1992, Royal Institution of Chartered Surveyors, London. RICS Publications, 33-44.

Male, S P and Mitrovic, D (2005) The project value chain: procuring supply chains in construction. Paper presented at the Cobra 2005 Conference, July 2005, Queensland University of Technology, Royal Institution of Chartered Surveyors.

Male, S P, Kelly, J R, Fernie, S, Gronqvist, M and Bowles, G (1998a) *The value management benchmark: a good practice framework for clients and practitioners.* Published Report for EPSRC IMI Contract. London: Thomas Telford.

Male, S P, Kelly, J R, Fernie, S, Gronqvist, M and Bowles, G (1998b) *The value management benchmark: research results of an international benchmarking study.* Published Report for EPSRC IMI Contract. London: Thomas Telford.

Male, S P, Kelly, J R, Gronqvist, M and Graham, D (2007) Managing value as a management style for projects. *International Journal of Project Management*, **25**(2), 107–14.

Moussa, N (1999) *The application of lean manufacturing concepts to construction: a case study of airports as large, regular-procuring, private clients*, Unpublished PhD Thesis, School of Civil Engineering, University of Leeds.

OGC (2007a) *Risk and value management*. Office of Government Commerce Achieving Excellence in Construction Procurement Guide No. 4.

OGC (2007b) Office of Government and Commerce www.ogc.gov.uk/delivery_lifecycle_requirements_management.asp (accessed 27 February 2007).

Robson, C (2002) *Real world research.* 2ed. Oxford: Blackwell Publishing.

Rosenhead, J (1989) *Rational analysis for a problematic world, problem structuring methods for complexity, uncertainty and conflict.* John Wiley & Sons.

Schon, D A (1991) *The reflective practitioner: how professionals think in action.* Reprinted 1999. Aldershot: Ashgate Publishing Ltd.

Smith, N J (2002) *Engineering project management*. 2ed. Oxford: Blackwell Publishing.

Smith, N J (2006) *Managing risk in construction projects*. Oxford: Blackwell Publishing.

Smith, N J and Afila, D (2007) Risk management and value management in project appraisal. Forthcoming in *Proceeding of Institution of Civil Engineers, Management, Procurement and Law.* London: Thomas Telford.

Smith, N J and An, M (2006) Risk analysis for construction tomorrow. Paper presented at the IPMA World Congress, October 2006, Shanghai.

Smith, N J and Mackie, P J (2005) Financing roads in Great Britain. *Research in Transportation Economics*, **15**, 223–37.

Smith, N J and Merna, A (1996) (Eds.) *Projects procured by privately financed concession contracts*, Vols 1 and 2. 2ed. Hong Kong: Asia Law & Practice Ltd.

Standing, N (2000) *Value engineering and the contractor*, Unpublished PhD Thesis, School of Civil Engineering, University of Leeds.

Standing, N (2005) Requirements management. Working Paper, School of Civil Engineering, University of Leeds.

Walker, P and Greenwood, D (2002) *Construction companion to risk and value management*. London: RIBA Enterprises.

Woodhead, R (1999) *The influence of paradigms and perspectives on the decision to build undertaken by large experienced clients of the UK construction industry*, Unpublished PhD Thesis, School of Civil Engineering, University of Leeds.

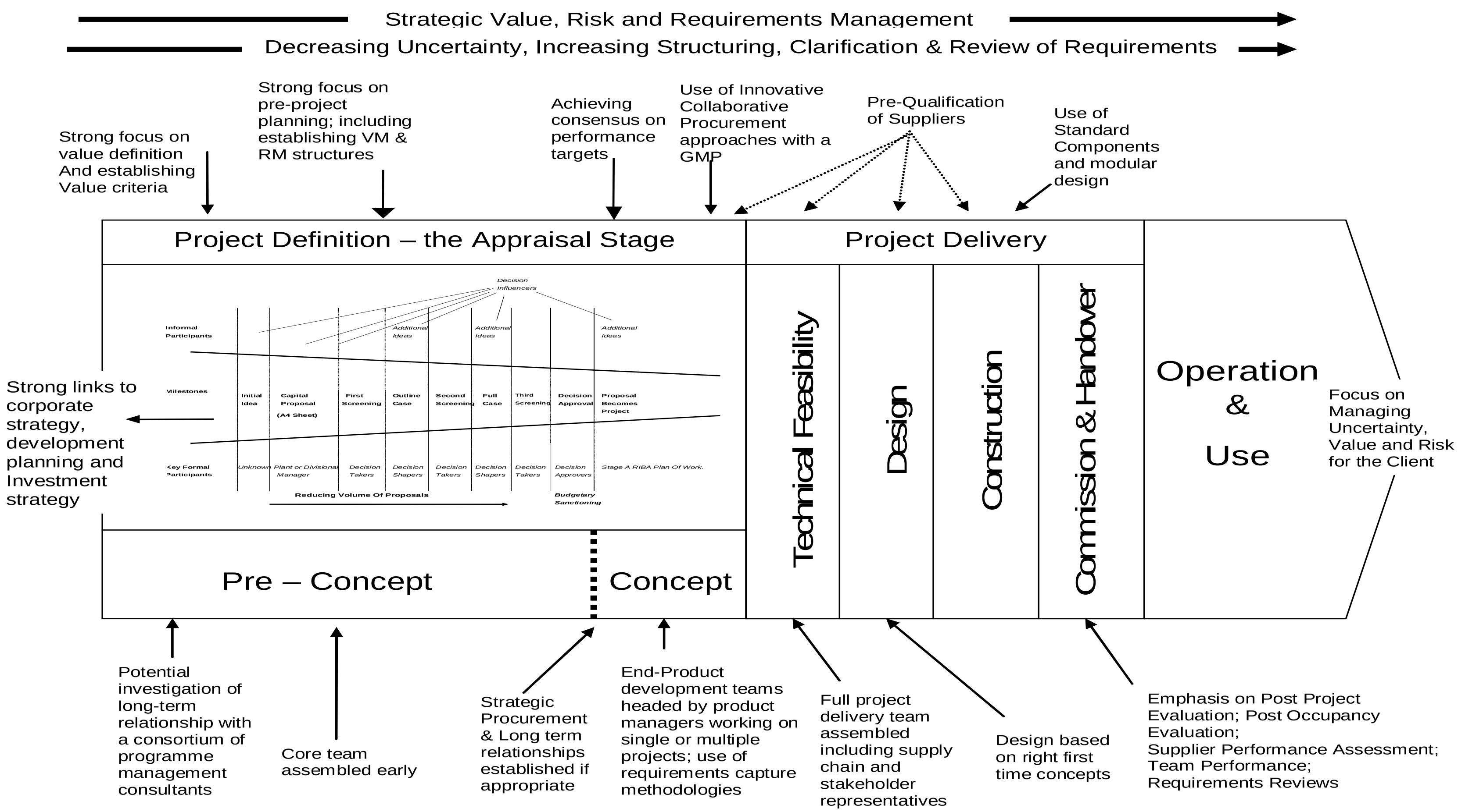


Figure 3: The formative stage of projects – the appraisal stage (adapted from Moussa 1999; Woodhead 1999 and fieldwork)

COMPREHENSIVE PERFORMANCE EVALUATION FACTORS FOR PUBLIC CONSTRUCTION PROJECTS

Shih-Tong Lu,[1] Chun-Nen Huang[2] and Yao-Chen Kuo[3]

[1] *Department of Risk Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*
[2] *Department of Security Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*
[3] *Department of Property Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*

Large-scale public construction projects take the majority of the government budget. Currently, the performance evaluation systems of government entities focus more on budget performing ratios or financial achievements. The life cycle of a large-scale public construction project includes budget allocation, planning and design, tendering, construction, inspection and acceptance and maintenance. All of these belong to an interrelated and integrated process, but they do not establish an effective overall evaluation model in government sectors. Although there are a few studies that propose evaluation indices or models for reference, these are mostly based on construction stages as weight datum. Therefore, this study adopts economy, efficiency and effectiveness (3E), proposed by Budaus and Buchholtz (1996), to construct a structure of the execution performance evaluation criteria, covering every stage of the life cycle of public construction project. This study applies the factor analysis and fuzzy analytic hierarchy process (FAHP) to find the important evaluation factors and their relative weight. It is expected to provide a reference for the relevant supervising sectors or audit offices of the government to evaluate and inspect the public construction projects.

Keywords: performance evaluation, public construction projects, 3E evaluation model, fuzzy analytic hierarchy process.

INTRODUCTION

The quality of public infrastructure is one of the most important elements affecting the economic development of a country. One of the world's renowned rating institutes of the competitiveness of different countries, the Institute for Management Development (IMD), sets the level of the development on public infrastructure as a critical index when evaluating the competitiveness of countries. Within the past few years, Taiwan's government has invested much effort to become more energetic, effective and efficient, and questions have been raised about whether government sectors are being overlapped and overstaffed, whether more financial funding is required for improvement, whether the government officers are well educated for updated rules and regulations, and whether project performance is well evaluated etc. All of these questions are important issues on the efficiency of the administrative of a government.

Recently, the performance evaluations of Taiwan's government sectors have mainly been restricted to the evaluation of their budget implementation rate. In other words,

[1] stonelu@mail.knu.edu.tw

the financial performance is the core part of the traditional performance system applied on different government sectors in Taiwan. However, in the large-scale public construction projects that take the majority of the government budget, the processes from budget allocation, planning and design, tendering, construction, completion and effectiveness after construction, the procurement of a construction belongs to an overall construction project. However, the government lacks a state-of-art model implemented for the evaluation of the overall construction process. Although Ho (1995), Chiang (1997) and Hsu (2004) conducted some studies for this issue, and suggested some indices and models associated with the addressed evaluations for references, most of them are established on the basis of assigning criteria to construction stages. In addition, Budaus and Buchholtz (1996) used a multi-dimension, economy, efficiency and effectiveness (3E) evaluation mode to construct a set of matrixes for the comprehensive performance evaluation of the government. The proposed model is also used to monitor the effectiveness of the administrative affairs in government sectors, and furthermore improve their financial balances. With regard to the construction and maintenance projects, the National Audit Office of ROC (1988) proposes many performance auditing methods and techniques, and also recommends the exploration of an evaluation model based on the performance perspective of 3E. However, those studies were only limited to the development of concept. There is no concrete indication as to which methods to adopt for a fair, objective and professional qualitative and quantitative performance measuring index in order to evaluate the public construction project to correspond to each construction stage, including budget allocation, planning and design, tendering, construction, inspection and acceptance and maintenance, in the life cycle of a construction project. Therefore, building a set of project performance evaluation models covering all stages of the life cycle of a public construction project to meet required qualities, times and costs is essential for the government. This is a very important objective when considering the sustainable development of a country. This study was conducted by considering three dimensions of economy, efficiency and effectiveness (3E) to construct the framework of the execution performance evaluation criteria, covering all stages of the life cycle of a public construction project. The factor analysis and fuzzy analytic hierarchy process (FAHP) were applied to investigating the critical evaluation factors and their related weight in this study. The results will be a set of important references for government sectors to evaluate the performance of the procurement and execution abilities of the construction projects in order to be successful in project control of construction projects.

LITERATURE REVIEW

In the past, only a few studies were conducted to investigate the project performance in public infrastructure construction projects. Based on the characteristics of public projects and the needs discovered during the construction stages of some infrastructure projects, Ho (1996) built a performance evaluation system that includes the functions of progress management, budget execution, quality management, administrative operation, environment management and so on, and established an integrated model to evaluate the performance of allocating and utilizing budget for project progressing. Compared to the past studies associated with project performance indices, Ho’s research revealed more related information in the management issue. Chiang (1997) constructed a model that measures the performance for the processes of closing project, controlling progress, managing cost, managing quality, controlling safety, managing hygiene and environment, administrating, and so on. Twenty critical indices were explored from conducting a questionnaire survey to twelve major infrastructure projects. Furthermore, the analytic hierarchy process (AHP) was utilized to determine the weight of each explored index, and finally the model including a set of the index used to evaluate the performance of a public construction project was proposed. The Construction Industry Institute (CII) developed a performance evaluation system, named as Quality Performance Measurement Structure (Steven et al. 1994) to measure the performance of the quality management in a construction project. They explored the significant performance indicators for the four major targeted fields and for each stage of the life cycle of a construction project, and furthermore determined the guideline of performance measurement for each explored indicator. Russell et al. (1996) established the Continuous Assessment of Project Performance (CAPP) for owner, engineer, and construction contractor organizations can use continuous or time-dependent variables, such as owner expenditures, construction effort hours expended etc., to predict project outcomes from start of detailed design through construction completion. Statistical analysis was performed to identify the significant indicators showing a statistically significant difference between the successful and less-than-successful project outcome. Results show that different indicators were predictors of success at different stage of the project life cycle. In addition, the research report conducted by the National Audit Office (1998) identified that there were many existed auditing methods and technical research directions that were found to be powerful to enhance project performance. The report adopts the 3E performance perspectives which were proposed by Budaus and Buchholtz (1996), and suggests multiple auditing concerns, as well as different evaluation models available for project development and performance measurement, such as ratio analysis, multiple-goal social science integrative evaluation approach and so on.

Although the reviewed studies have provided some indices and models for the performance evaluation of public construction projects, most of them were developed only for the construction stage, and for single dimension of 3E. They are not pursuable to be used for the performance evaluation for a overall public construction project since they were developed without the input of the information at all stages of the life cycle of a public construction project. Therefore, it is urgent to develop an evaluation method that includes the information at all stages of the life cycle of a public construction project, in order to practically measure the overall performance of a public construction project.

FUZZY HIERARCHICAL ANALYSIS FOR PROJECT PERFORMANCE FACTORS

Establishment of the hierarchal structure of evaluating project performance

At the beginning of this study, based on the interviews with experts and scholars associated with construction management, a hierarchical system of evaluating project performance, shown on Figure 1, was established in three dimensions of economy, efficiency and effectiveness (3E). Sixty-five indicators were identified as critical factors affecting project success of a construction project. Among the 65 indicators, 25 indicators are related to economy performance; 26 and 14 indicators are respectively related to efficiency performance and effectiveness performance.

Figure 1: Hierarchy of evaluating project performance

Determining the evaluation factor weights

In general, the factors used to evaluate the performance of a construction project are different on the levels of significance to influence project success. Many methods were employed to determine the level of significance of the effects on the project performance, such as the eigenvector method, weighted least square method, entropy method etc. (Hwang and Yoon 1981). The AHP developed by Saaty (1980) is a very powerful tool to assist users to carry decision making with multiple criteria, and has successfully been applied to many related cases in the construction industry (Mahdi *et* *al*. 2002; Al Khalil 2002; Cheung *et al*. 2002). However, during the operation of AHP implementation, it is easier and more humanistic for evaluators to choose "criterion A is much more important than criterion B," than "the importance of principle A and principle B is seven to one". Hence, Buckley (1985) updated Saaty's AHP to the case where the evaluators are allowed to employ fuzzy ratios in place of exact ratios to handle the difficulty in assigning exact ratios when comparing two criteria, and derive the fuzzy weights of criteria from geometric mean method. Therefore, in this study, we employ Buckley's method, Fuzzy Analytic Hierarchy Process (FAHP), to fuzzify hierarchical analysis by allowing fuzzy numbers for the pair-wise comparisons, and find the fuzzy weights as the level of significance of the effects of factors on project performance.

Fuzzy Analytic Hierarchy Process (FAHP)

The procedure for determining the performance factors weights by FAHP can be summarized as follows:

Step 1: define a linguistic variable

A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Five basic linguistic terms – "absolutely important," "very strongly important," "essentially important," "weakly important," and "equally important" with respect to a fuzzy five level scale (Figure 2) – were utilized to compare two project execution performance. (Chiou and Tzeng 2001) The scale of fuzzy number on the five basic linguistic terms had been defined by Mon *et al*. (1994), see Table 1, and was applied in this study to determine the weights of evaluation criteria. Each membership function, by means of scale of fuzzy number, is defined by three parameters of the symmetric triangular fuzzy number (TFN), the left point, middle point and right point of the range over which the function is defined.

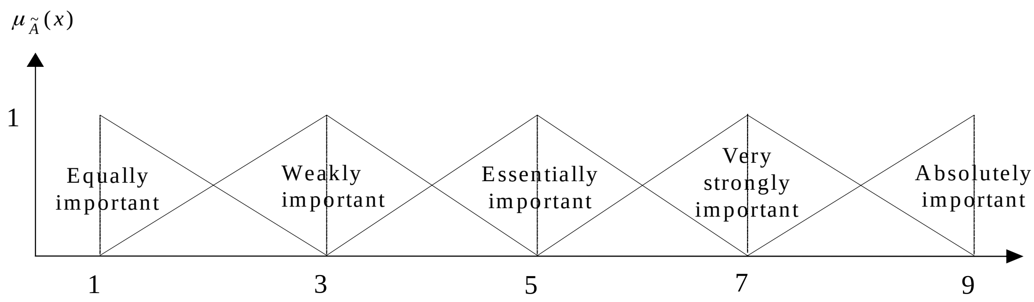


Figure 2: Membership function of linguistics variables for comparing two factors

Table 1: Membership function of linguistic scale

Fuzzy number	Linguistic scales	Scale of fuzzy number
$\tilde{1}$	Equally important (Eq)	(1,1,3)
$\tilde{3}$	Weakly important (Wk)	(1,3,5)
$\tilde{5}$	Essentially important (Es)	(3,5,7)
$\tilde{7}$	Very strongly important (Vs)	(5,7,9)
$\tilde{9}$	Absolutely important (Ab)	(7,9,9)

Note: this is synthesized from the linguistic scales defined by Chiou and Tzeng (2001) and the fuzzy number scale used in Mon *et al*. (1994).

Step 2: construct pair-wise comparison matrices among all the factors in the dimensions of the hierarchy system
Assign linguistic terms to the pair-wise comparisons by asking which is the more important between any two factors, such as

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \tag{1}$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9}, & \text{factor } i \text{ is relative importance to factor } j \\ 1, & i = j \\ \tilde{1}^{-1},\tilde{3}^{-1},\tilde{5}^{-1},\tilde{7}^{-1},\tilde{9}^{-1}, & \text{factor } i \text{ is relative less importance to factor } j \end{cases}$$

Step 3: Use geometric mean technique to define fuzzy geometric mean and fuzzy weights of each criterion
Use the geometric mean technique proposed by Buckley (1985) to define the fuzzy geometric mean and fuzzy weights of each criterion as follows:

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{in})^{1/n}, \quad \tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_n)^{-1} \tag{2}$$

where $\tilde{a}_{in}$ is the fuzzy comparison value of performance factor *i* to performance evaluation *n*, thus, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of performance factor *i* to each performance factor , $\tilde{w}_i$ is the fuzzy level of significance of the i^{th} performance factor, which can be formulated using a TFN, $\tilde{w}_i = (Lw_i, Mw_i, Uw_i)$. Here Lw_i, Mw_i and Uw_i are respectively for the low, medium and high values of the fuzzy level of significance of the i^{th} performance factor.

Step 4: defuzzify the fuzzy numbers
The fuzzy weights reached by pairwise comparison of each factor are a fuzzy number. Therefore, it is necessary that a non-fuzzy method for fuzzy numbers be employed for comparison of each factor. In other words, the step of defuzzifying the fuzzy numbers is to locate the Best Non-fuzzy Performance value (BNP). Methods applied to such step include mean of maximal (MOM), centre of area (COA), and α-cut (Teng and Tzeng 1996). Because it is not required to bring in the preferences of any assessor, and it is simple and practical for the COA method to figure out the BNP, COA method was used to defuzzify the fuzzy numbers in this study. The *BNP* value of the fuzzy number $\tilde{R}_i$ can be obtained with the following equation:

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i, \quad \forall\, i \tag{3}$$

RESEARCH RESULTS

In this study, factor analysis was first implemented to explore the factors with significant impacts on the performance of Economy, Efficiency and Effectiveness associated with overall project performance. The significant factors of each dimension are presented in Figure 3. For the dimension of Economy, 11 out of 25 factors were considered as the factors with significant impacts on the overall project performance. For the dimension of Efficiency, 11 out of 26 factors with significant impacts, and 9 out 24 for the dimension of Effectiveness. Secondly, FAHP was applied to determining the weights of the explored factors from factor analysis depending on their impacts on the overall project performance of a public construction project.

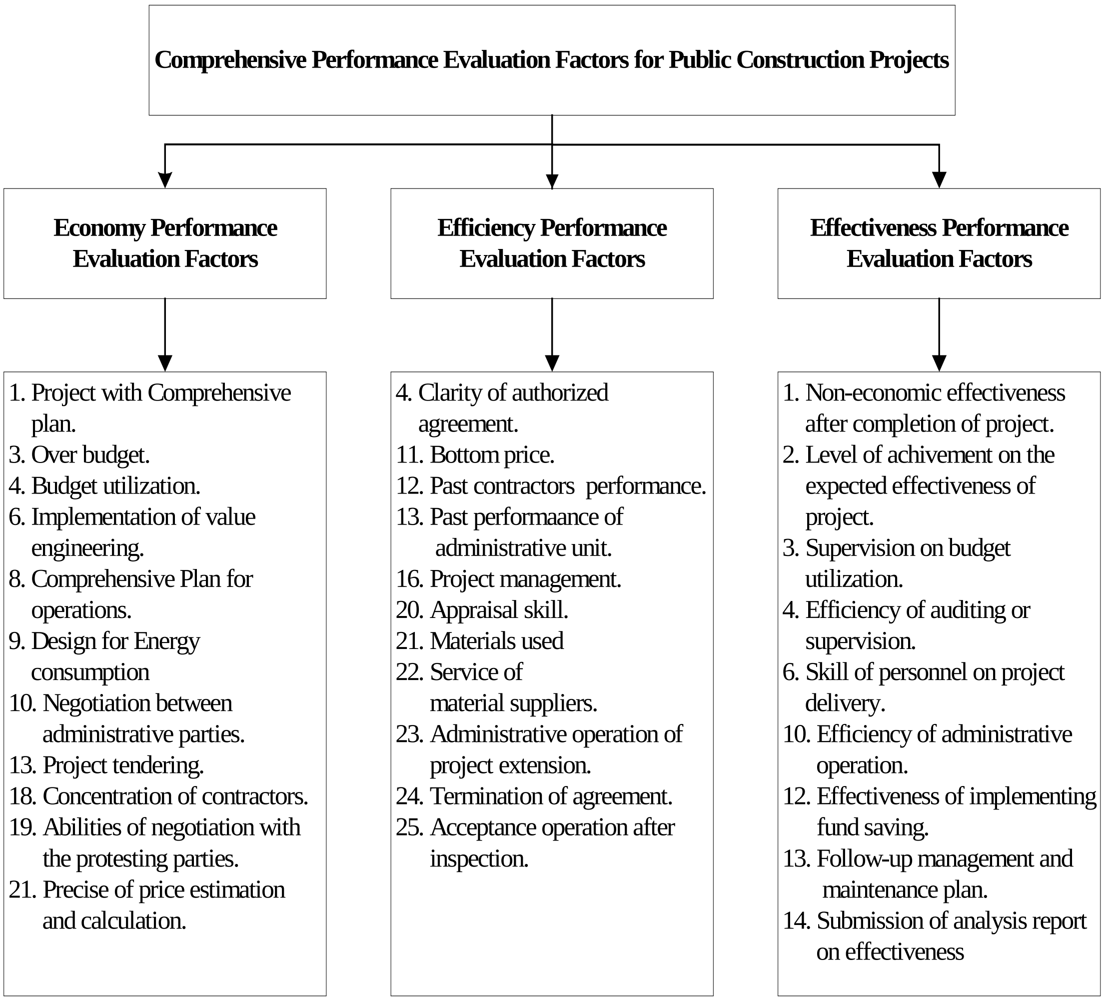


Figure 3: The major factors of each performance evaluation dimension

Based on the results of the FAHP analysis shown in Table 2, the order of level of significance for economy performance factors are: planned operation, comprehensively planned project, energy-saving situation, concentration of contractors, administrative negotiating abilities, negotiating abilities with the protesting public, situation of the use of valuable engineering, situation of price estimation and calculation, situation of budget digesting overbudgeting situation and situation of project tendering.

The order for efficiency performance factors are: materials of project, rear-service supply of materials, appraisal ability, allocation of bottom price, abilities of administrative unit, acceptance operation after inspection, project management, the clarity of authorized agreement, administrative operation of project extension, abilities of contractors and procedures for termination of agreement.

The order for effectiveness performance factors are: follow-up management and maintenance plan, effectiveness of auditing or supervision, namely the non-economic effectiveness after completion of project, efficiency of administrative support, effectiveness of implementing fund saving, execution abilities of personnel, submission of effectiveness analysis report, accomplishment degree of expected effectiveness of project and supervision on budget execution.

Table 2: The weights of major factors of each performance evaluation dimension

Economy performance		**Efficiency performance**		**Effectiveness performance**	
Factors	**Weights**	**Factors**	**Weights**	**Factors**	**Weights**
Project with comprehensive plan	0.1033	Clarity of authorized agreement	0.0963	Non-economic effectiveness after completion of project	0.1185
Over budget	0.0701	Bottom price	0.1048	Level of achievement on the expected effectiveness of project	0.1042
Budget utilization	0.0830	Past contractors performance	0.0659	Supervision on budget utilization	0.0937
Implementation of value engineering	0.0925	Past performance of administrative unit	0.0989	Effectiveness of auditing or supervision	0.1191
Comprehensive plan for operations	0.1069	Project management	0.0982	Skill of personnel on project delivery	0.1088
Design for energy consumption	0.1033	Appraisal skill	0.1050	Efficiency of administrative operation	0.1149
Negotiation betweenadministrative parties	0.0967	Materials used	0.1129	Effectiveness of implementing fund saving	0.1093
Project tendering	0.0557	Service of material suppliers	0.1092	Follow-up management and maintenance plan	0.1235
Concentration of contractors	0.1032	Administrative operation of project extension	0.0683	Submission of analysis report on effectiveness	0.1080
Abilities of negotiation with the protesting parties	0.0939	Termination of agreement	0.0422		
Precise of price estimation and calculation	0.0914	Acceptance operation after inspection	0.0984		

CONCLUSION AND RECOMMENDATION

Conclusion

1. Through the interviews with government officials, it was found that government sectors did not have a reliable performance evaluation system available for project control and management of public construction projects. This purpose of this study is to employ Fuzzy Multiple Criteria Evaluation (which corresponds to the management behaviours of human beings and is now widely employed in many academic studies) to establish a nationwide performance evaluation system for the project delivery of public construction projects.

2. This study underwent qualitative and quantitative analyses on the selection and the weights determination of significant performance indicators across all stages of the life cycle of public construction projects. At first, a questionnaire survey was conducted and then factor analysis was performed to identify the indicators considered as significant factors affecting overall project performance by the experts and scholars in construction management field. Secondly, FAHP was applied to determining the weight of the explored factor, as the level of significance on the impacts on project performance. Through the two steps addressed above, a state-of-art performance evaluation model was built to be objective, reliable, practical and operational for government sectors to evaluate the overall performance of public construction projects.
3. Through this study, many criteria that significantly affect the project performance identified by the experts in construction management field are explored. After collating the opinions of experts, it was found that the impacts of economy, efficiency and effectiveness on the project delivery performance of public construction projects are 32.4%, 33.5% and 34.1% respectively. It is believed that theses three dimension have a similar size of effects on the project delivery performance of public construction projects. However, the dimension of effectiveness performance has the highest concerns, and the dimension of economy performance has the least.

Recommendations

1. This study established the evaluation model mainly based on the financial performance, and yet has not completely included the realm of financial performance. Although the factor analysis and FAHP were used to develop the performance evaluation model in this study, it is suggested that other analytic double-check procedures could be studied and developed in advance to compare the merits and demerits, as well as the applicability of implementing different approaches. In addition, the evaluation criteria can be transformed to the format of ratio to reflect the financial criteria, such as the different financial ratios, operation ratio, proficiency ratio, growth ratio, and so on. With the input of more information, a new complete performance evaluation model related to the proficiency of business operation can be successfully developed.
2. This study divided different evaluation criteria into three groups: economy, efficiency and effectiveness (3E). However, some of the criteria – such as whether the plan and design are well performed, whether new construction methods and new regulations (e.g. slope development and vibration resistance standards, etc.) are well identified and considered as alternatives in the plan and design stages, whether there is any required change due to improper design during construction period, or any increase on the public expenses, and difficulties of maintenance in the later days, or reduction in valid life and increase in needs of additional maintenance and remodel – are related to both dimensions of the efficiency and the economy. It is difficult to put a criterion addressed above to any to the 3E dimensions. Therefore, it is suggested that the evaluation criteria can be grouped according to the following categories: planning, design, public bidding, tendering, construction, acceptance after inspection, and proficiency after completion of construction. It is believed that it is easier to classify the criteria into several groups before any analysis is performed.

REFERENCES

Al Khalil, M I (2002) Selecting the appropriate project delivery method using AHP. *International Journal of Project Management*, **20**(6), 469–74.

Buckley, J J (1985) Ranking Alternatives Using Fuzzy Numbers. *Fuzzy Sets and Systems*, **15**(1), 21–31.

Budaus, D and Buchholtz, K (1996) Controlling local government cost and performance. *In:* J L Chan, R H Jones and K G Luder (Eds.) *An international comparison. Research in Government and Nonprofit Accounting 9*. London: Jai Press.

Cheung, F K T, Kuen, J L F and Skitmore, M (2002) Multi-criteria evaluation model for the selection of architecture consultants. *Construction Management and Economics*, **20**(7), 569–80.

Chiang, C M (1997) *A Study of Execution Performance Evaluation System and Examination Indicators of Public Project*, unpublished Master Thesis, Graduate School of Construction Engineering, National Taiwan University of Science and Technology.

Chiou, H K and Tzeng, G H (2001) Fuzzy hierarchical evaluation with grey relation model of green engineering for industry. *International Journal of Fuzzy System*, **3**(3), 466–75.

Ho, C C (1996) *Performance Evaluation Model on Project Implementation of Public Construction*, unpublished Master Thesis, Graduate School of Construction Engineering, National Taiwan University of Science and Technology.

Hsu, C H (2004) *A Study on Project Execution Performance Evaluation of Construction Engineering Testing Feasibility of PDRI Model*, unpublished Master Thesis, Graduate School of Construction Engineering, National Yunlin University of Science and Technology.

Hwang, C L and Yoon, K (1981) *Multiple Attribute Decision Making: Methods and Applications*. New York: Springer-Verlag.

Mon, D L, Cheng, C H and Lin, J C (1994) Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight. *Fuzzy Sets and Systems*, **62**(2), 127–34.

Mahdi, I M, Riley, M J, Fereig, S M and Alex, A P (2002) A multi-criteria approach to contractor selection. *Engineering, Construction and Architectural Management*, **9**(1), 29–37.

National Audit Office (1998) *How to enhance auditing methods and techniques for performance of construction and maintenance projects so as to reveal the auditing performance*, National Audit Office Research Report.

Saaty, T L (1980) *The analytic hierarchy process*. New York: McGraw-Hill.

Teng, J Y and Tzeng, G H (1996) Fuzzy Multicriteria Ranking of Urban Transportation Investment Alternatives. *Transportation Planning and Technology*, **20**(1), 15–31.

Yuan, Y J (2001) *A Study on the Strategic Performance Evaluation Measures for the Execution of Public Construction Budgets – An Application of the Balanced Scorecard*, unpublished Master Thesis, Graduate School of Accounting, Chun Yuan University.

A REAL OPTIONS APPROACH TO MEASURE THE TOTAL VALUE OF A PPP PROJECT

Michaela M. Schaffhauser-Linzatti[1] and Bettina Schauer[2]

[1]*Department of Business Administration, University of Vienna, Bruenner Strasse 72, 1210 Vienna, Austria*
[2]*Institute for Mathematical Methods in Economics, Vienna University of Technology, Wiedner Hauptstrasse 8/E105, 1040 Vienna, Austria*

Public–private partnership (PPP) has gained recognition in financing and managing ventures of public interest by involving private investors. Among others, the public party has to decide which partners to choose; the private party is at first concerned whether to participate anyway. We apply a real options approach to solve both questions. Adapting the underlying model to the specific PPP design, a call value is attached to each possible partnership. To do so, the model is flexible enough to be adapted to any specific PPP construction. As main parameters we introduce a statistical estimate of the underlying service's use as well as fixed and variable fees offered by the potential private partners. The results offer a comprehensive decision basis for all parties concerned.

Keywords: decision support, investment, models, public–private partnership, real options.

INTRODUCTION

Financial restraints of public budgets enforce the inclusion of private initiatives to support public ventures like building, renewing or operating infrastructure of public interest. Numerous concepts operating under the term public–private partnership (PPP) combine the multiple interests of public as well as private partners (Montanheiro 2002). In general, each of the partners participates in a joint project like motorway construction or railway operation and supports it with their individual strengths. Among other things, public institutions may provide a better credit risk and special rights, private organizations know-how and financing. The particular role of each partner is subject to a comprehensive, project-specific contract. The application of PPP projects has been introduced by politicians and practitioners and is now common use internationally.

Academic employment on PPP, however, did not gain recognition until the first empirical projects were finished. Most of the published work is descriptive; theoretical aspects are still underrepresented (Knudsen *et al.* 2001). They mainly concentrate on the interplay between the partners by applying game theory and principle–agent theory (see 'Theoretical framework' below), but do not pay adequate attention to model-based evaluation approaches. So far, well-known instruments developed for other evaluation problems have not been employed to PPP project calculations in spite of their appropriateness. Among these approaches, real option pricing seems to be

[1] michaela.linzatti@univie.ac.at

promising, mainly because it allows for simultaneously regarding the different perspectives of the divergent stakeholders and for incorporating uncertainty. This uncertainty relates to the expected future benefits resulting from the joint project, e.g. to what extent the services being offered are accepted, and consequently to the returns of these services.

This paper focuses on the question how to evaluate a PPP project by means of a real options model. Real options theory applies classic option pricing to real investments; the term ‘real option’ is used to distinguish options arising in contexts other than purely financial ones, e.g. in the pharmaceutical, biotech, petroleum and energy industries (see Boer 2002). In general, an option provides the right to buy or sell an asset, originally a stock, for a predetermined price at some point in time in the future. The holder of the option is not forced to exercise this right, and will only do so if it seems to be opportunistic. PPPs are real projects per definition; hence, real options theory is a promising approach as the decision to exercise an option is very similar to decisions taken in PPP projects, e.g. when deciding whether to participate and thus invest in a partnership.

Regarding a PPP project as an option offers the flexibility to model the enhancement, delay or termination of the partnership depending on whether conditions turn out favourably, which can be modelled by using the option to expand, to defer or to abandon (see Trigeorgis 1996). Thus, real options evaluation incorporates comprehensive and dynamic aspects in contrast to the more or less static treatment of costs and revenues applied so far. We show that our real options model offers an adequate theoretical approach for PPPs with a straightforward implementation.

The paper is structured as follows. The next section describes the theoretical framework of real options models, concentrating on their structures and fields of application. The third section derives our real options model adapted for PPP evaluation; the fourth section discusses its practical use and limitations; finally the concluding section summarizes the results.

THEORETICAL FRAMEWORK

Among the theoretical approaches to decide on PPP problems, game theory and net present value based models have been mostly applied so far. Game theory models strategies of decision makers as well as information available concerning the status of competitors (von Neumann and Morgenstern 1944), while using decision theory the agents play against nature (Arrow 1957; Raiffa 1997). Hereby, the popular decision tree analysis demands the complex and time-consuming assignment of probabilities to uncertain variables and preferences to uncertain outcomes (Poh *et al.* 2001). Principal–agent models (Ross 1973) have been recently applied for PPP (Pongrisi 2004); however, they concentrate on the exploitation of information asymmetry to maximize revenues and not on valuation (Renzetti and Dupont 2003; Trebilcock and Iacobucci 2003). Finally, the traditional economic models based on cash flows require satisfyingly fixed conditions and constant discount rates and hence undervalue high risks in long-term projects (Amran and Kulatilaka 1999; Graves and Ringuest 2003).

Real options analysis does not face these – partially prohibitive – drawbacks. It is well suited for projects with a high level of exogenous and partly endogenous uncertainties (Neely 1998) like the market pay-off, budget, performance, market requirements and schedule uncertainty (Huchzermeier and Loch 2001) as it retraces the projects’ continually changing processes, rewards risk taking, and is able to evaluate project options on the price path of traded assets in the sense of financial investment opportunities (Myers 1977). To do so, the binominal model and the Black–Scholes formula can be applied.

The multiplicative binomial option pricing model by Cox and Rubinstein (1979) is based on constructing a replicating portfolio and determining its costs in order to determine the value of the option equivalent. Its iterative process divides the time of expiration into discrete steps similar to the decision tree analysis. However, Trigeorgis (1996) points out the disadvantages for evaluation of long-term projects. First, the underlying decision trees quickly become unmanageable as they grow exponentially with the numbers of decisions. Second, appropriate, and most probably changing discount rates over the whole period have to be found. Finally, the call value in the binomial model converges to the results of the Black–Scholes formula in case of $t \rightarrow \infty$.

If long-term statistical records are available to measure the risk of an underlying asset by determining the volatility of the price movements and thus the volatility of the rate of return such as for financial assets, the Black–Scholes formula for option pricing (Black and Scholes 1973) can be applied for real projects. However, there is usually no volatility observable for real projects. Thus, historical data from similar projects can be used as an approximation, or the volatility is derived through estimations of the value of future cash flows and the consequent deviation (Perlitz *et al.* 1999). The Black–Scholes formula uses the input parameters S = current value of the underlying asset, K = strike price of the option, t = life of option expiration, r = riskless interest rate corresponding to the life of the option, σ^2 = variance of the underlying asset, and $\Phi(.)$ = the cumulative normal density function:

$$v = S\Phi(d_1) - Ke^{-rt}\Phi(d_2)$$

$$\text{where } d_1 = \frac{\left(ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right) t \right)}{\sigma\sqrt{t}},\ d_2 = d_1 - \sigma\sqrt{t}$$

By analogy to the financial options evaluation with Black–Scholes, the expected benefits of a PPP project correspond to the stock price, the project costs to the strike price, the date on which the implementation of the project is decided on to the exercise date, and the variance of the expected benefits to the volatility. The long-time maturity enforces an adaptation of some input parameters like the risk-free interest rate. As the project is not traded such as financial options, Perlitz *et al.* (1999) suggest deriving the underlying asset by spanning, i.e. creating a twin security by duplicating cash flows of the non-traded asset to a traded portfolio, by hotelling, i.e. estimating the market potential of the future products of the projects, or by future cash flows.

MODEL

In its basic outline, the real options model is based on a BOT (build–operate–transfer) structure of a PPP project (Akintoye *et al.* 2003). In such a structure, the private partner builds and operates the project which is transferred to the public partner at a known time. Until then, the public partner supports the project, among other things, by granting special rights or by taking credit risks, and is rewarded by fees. Hence, a real options model has to comprise computational decision bases for both partners.

Underlying assumptions

We suppose one public and a number of potential private partners i, with n being the total number of potential private partners i. The public partner is in search of the best private partner in order to share risk, know-how and investment. Each private partner must decide whether to make an offer, and, in the event of participation, decide on an offer of the fee payments. Note: To simplify the BOT-model without reducing its explanatory power, we incorporate the transfer step as follows. After finalization of the project in period T, the public partner pays a redemption rate R which is fixed at the beginning of the partnership to the private partner. To integrate R into the model without further calculation in T, R is discounted by a constant interest rate r_c which is also fixed in advance, increases the investment of the public partner and reduces the initial costs of private partner in t = 0, respectively. Hence, I and C_0 in the model (see Equations 6 and 12 below) are already adjusted by the discounted R.

As an example, the model is embedded into the realistic and frequently used application of PPP motorway building and operating. The public partner plans to enlarge the motorway network by a specific route and chooses to take in a private partner.

Each possible private partner offers to pay the public partner an annual total fee (TF) which consists of a fixed and a variable part, F_f = fixed fee and F_v = variable fee.

$$TF = F_f + F_v*q \qquad (1)$$

where the uncertain variable q equals the total number of driven kilometres (or quantity consumed) by the customers. q is estimated by the public as well as by each private partner independently and is supposed to follow a normal distribution with mean $\mu = \mu(p)$ and standard deviation $\sigma = \sigma(p)$. q is correlated to the road charge p (or any fee) the customers have to pay. p is determined by each private partner:

$$q = q(p) \qquad (2)$$

In this price–demand function q is assumed to be a monotonically decreasing function of p; a quantity q_0 might be assumed not to be exceeded even if the service is offered for free.

Hence, the total earnings (TE) of the private partner are:

$$TE = p*q. \qquad (3)$$

Beside the TF pay-offs to the public partner, each private partner faces additional total costs (TC) to third parties, C_f = fixed costs and C_v = variable costs per kilometre:

$$TC = Cf + Cv*q \qquad (4)$$

Thus, the total pay-off (TP) of a private partner consists of TF and TC:

$$TP = TF + TC \qquad (5)$$

As easily can be shown, TP converges asymptotically towards $C_f + F_f$.

Public partner

The decision of the public partner is to find the optimal private partner i, which is the partner yielding the highest call value V_i. To make a profit, V_i must not be negative for the public partner in any case (for introducing welfare, see Discussion, below). Note: The project requires another investment cost I which might occur, e.g. because of legal requirements or acquisition of realty. I is assumed to be independent of the private partner and has to be paid by the public partner.

Hence, the optimization criterion is to maximize the call value V_i of the public partner's decision:

$$Vi = TF\Phi(d1) - I * e{-}rt\Phi(d2) \tag{6}$$

$$\text{where } d_1 = \frac{\left(ln\left(\frac{TF_i}{I}\right) + \left(r + \frac{\sigma^2}{2}\right)t\right)}{\sigma\sqrt{t}},\ d_2 = d_1 - \sigma\sqrt{t}$$

Consequently it follows:

Do not invest, if $\max_{i=1}^{n}(V_i) < 0$ (7a)

Choose the private partner *i* yielding $\max_{i=1}^{n}(V_i)$ (7b)

Private partner

The decision of each private partner is to make an offer for TF, consisting of F_v and F_f, depending on each private partner's choice for p and according expectation for q. Hence, the optimization criteria are first to find the equilibrium (Equation 10) of marginal revenues (MR) (Equation 8) and marginal costs (MC) (Equation 9), and second to determine the decision's call value V (Equation 11). Note: The private partner has to invest another C_0 which refers to the initial investment for offering the service (e.g. building the motorway).

Assuming that the private partner defines the price p per kilometre and the kilometres driven q are a function of the price *q = q(p)* the marginal revenue corresponds to:

$$MR = \frac{dTE}{dq} = \frac{d(p * q)}{dq} = p \tag{8}$$

$$MC = \frac{d(TC + TF)}{dq} = \frac{d(C_f + C_V * q(p) + F_f + F_V * q(p))}{dq} =$$

$$\frac{d((C_V + F_V) * q(p))}{dq} = C_V + F_V \tag{9}$$

$$p_{\lim} = C_V + F_V \tag{10}$$

The call value of a private partner's investment decision is given by

$$V = TE\Phi(d1) - (TP) * e{-}rt\Phi(d2)$$

$$\text{where } d_1 = \frac{\left(ln\left(\frac{TE}{TP}\right) + \left(r + \frac{\sigma^2}{2}\right)t \right)}{\sigma\sqrt{t}},\ d_2 = d_1 - \sigma\sqrt{t} \tag{11}$$

Consequently it follows:

$$\text{Invest, if } V > C0 \tag{12}$$

DISCUSSION

The real options model presents an evaluation approach for a PPP motorway project with a BOT structure, in which one public partner chooses among a number of private partners to cooperate with. Of course, multiple enlargements of the model are possible.

The model can be applied to all construction and building projects as well as to services for which PPP is generally applicable.

It can also be easily extended to partnering structures other than BOT. In such cases, additional variables like different quantity measures or fixed investments might possibly be introduced. Note that according to the application, F_{fi} could also vary per time period yielding F_{fij} with j being the index of the period.

Some PPPs include contractually guaranteed minimum sales, i.e. the private partner ensures a minimum q_i and consequently a minimum total F_{vi}. This case can be easily implemented into the model by including the minimum $F_{vi} * q_i$ into F_{fi}.

In this model, p is assumed to be determined by each private partner independently. However, lower and/or upper price limits might be introduced by the government.

Interrelations among the public and private partners can be included into the model by combining the real options model with game theoretic aspects. The combination of real options and game theory has already been applied to model the interrelations between partners and competitors within the scope of R&D projects (Grenadier 2000a, b; Weeds 2002; Lambrecht and Perraudin 2003).

It is easy to modify the model, when public and private partners agree on constant percentages among fixed and variable fees, lower and upper boundaries of such percentages, or a split of the realized revenues, fixed or variable costs.

Public projects should not be carried out only for financial gain, but mainly to increase public welfare. Direct financial reliefs for customers such as price reductions or remissions are easy to include in the model. Non-monetary, indirect or long-term reliefs such as environmental pollution or safety aspects force the introduction of welfare parameters well known in economics (Varian 1999). Such social cost–benefit calculations are best introduced into the model by either increasing the annual F_f or by including a welfare ratio into F_v. In such cases, Equation 7a has to be modified accordingly.

CONCLUSIONS

This paper develops a real options model for evaluating PPP projects. By adapting the Black–Scholes formula for financial options, we show that this approach is suitable as a decision basis for all participating parties (a) whether to take part in such a joint project; and (b) which partner to choose. Hereby, the public partner invites private partners to build and operate a project of public interest and transfer it back after a previously defined time. The public partner makes the initial investments and in turn receives fixed and variable fees from the private partner. Each party is willing to join the project if the value of their call option exceeds their initial investment for acquiring the option. The public partner enters into partnership with the partner offering the highest return. Our model covers uncertainty and is flexible enough to integrate possible further enlargements. It reflects realistic conditions and can easily be implemented.

REFERENCES

Akintoye, A, Beck, M and Hardcastle, C (2003) *Public–private partnerships: managing risks and opportunities.* Oxford: Blackwell Publishing.

Amran, M and Kulatilaka, N (1999) *Real options – managing strategic investment in an uncertain world*. Boston: Harvard Business School Press.

Arrow, K J (1957) Decision theory and operations research. *Operations Research*, **5**(6), 765–74.

Black, F and Scholes, M (1973) The pricing of options and corporate liabilities. *Journal of Political Economy*, **81**(3), 637–54.

Boer, P F (2002) *The real options solution: finding total value in a high risk world.* Mississauga: John Wiley & Sons Inc.

Cox, J C and Rubinstein, M (1979) Option pricing: a simplified approach. *Journal of Financial Economics*, **7**(3), 229–63.

Graves, S B and Ringuest, J L (2003) *Models & methods for project selection – concepts from management science, financial and information technology.* Dordrecht: Kluwer Academic Publishers.

Grenadier, S R (2000a) Option exercise games: the intersection of real options and game theory. *Journal of Applied Corporate Finance*, **13**(2), 99–107.

Grenadier, S R (Ed.) (2000b) *Game choices: the intersection of real options and game theory*. London: Risk Books.

Huchzermeier, A and Loch, C H (2001) Project management under risk: using the real options approach to evaluate flexibility in R&D. *Management Science*, **47**(1), 85–101.

Knudsen, K, Lichty, R and Stewart, K (2001) Five years of public and private partnerships conference proceedings: a typology. *In*: L Montanheiro and M Spiering (Eds.) *Public and private partnerships: the enterprise governance.* Sheffield: SHU Press.

Lambrecht, B M and Perraudin, W (2003) Real options and pre-emption under incomplete information. *Journal of Economic Dynamics and Control*, **27**(4), 619–43.

Montanheiro, L (2002) Public–private partnerships: what are their true colours? *In*: L Montanheiro, S Berger and G Skomsøy (Eds.) *Public and private sector partnerships: exploring co-operation.* Sheffield: SHU Press.

Myers, S C (1977) Determinants of corporate borrowing. *Journal of Financial Economics*, **5**(2), 147–75.

Neely, J E (1998) *Improving the valuation of research and development: a composite of real options, decision analysis and benefit valuation frameworks*, Unpublished PhD Thesis, MIT, Cambridge.

Perlitz, M, Peske, T and Schrank, R (1999) Real options valuation: the new frontier in R&D project evaluation. *R&D Management*, **29**(3), 255–69.

Poh, K L, Ang, B W and Bai, F (2001) A comparative analysis of R&D project evaluation methods. *R&D Management*, **31**(1), 63–75.

Pongsiri, N (2004) Partnerships in oil and gas production-sharing contracts. *International Journal of Public Sector Management*, **17**(4/5), 431–42.

Raiffa, H (1997) *Decision analysis: introductory readings on choices under uncertainty*. Columbus: McGraw-Hill.

Renzetti, S and Dupont, D (2003) Ownership and performance of water utilities. *Greener Management International*, **42**(summer), 9–19.

Ross, S A (1973) The economic theory of agency: the principal's problem. *American Economic Review*, **63**(2), 134–9.

Trebilcock, M J and Iacobucci, E M (2003) Privatization and accountability. *Harvard Law Review*, **116**(5), 1422–53.

Trigeorgis, L (1996) *Real options: managerial flexibility and strategy in resource allocation*. Cambridge, MA: The MIT Press.

Von Neumann, J and Morgenstern, O (1944) *Theory of games and economic behaviour*. Princeton: Princeton University Press.

Varian, H R (1999) *Intermediate microeconomics: a modern approach.* New York: W. W. Norton & Company, Inc.

Weeds, H F (2002) Strategic delay in a real options model of R&D competition. *Review of Economic Studies*, **69**(3), 729–47.

THE HIERARCHY AND RELATIONSHIP OF PROJECT PERFORMANCE CRITERIA IN INDIAN CONSTRUCTION PROJECTS

K.N. Jha[1] and M.N. Devaya[2]

Department of Civil Engineering, Indian Institute of Technology Delhi, Hauz Khas, New Delhi-110016, India

The assessment of the success of a project has always been a subject of debate because of the large number of criteria by which the various participants of a project would like to assess the project. The aim of this study is to identify the important success criteria, arrange them in a hierarchy, and analyse the relationships among them in order to present to a project manager a 'bird's eye view' of the criteria that need to be concentrated upon depending upon the role of each criterion in terms of its ability to influence other criteria. Twenty-two criteria were identified from published literature and the most important 14 were selected based on a questionnaire survey, where the respondents were asked to rank each of the criteria in terms of its importance. These 14 criteria were then analysed using ISM and Micmac analysis. The results show that efficiency of project execution is the most influential criterion. The methodology presented in the study could be useful in several areas of construction management.

Keywords: India, project management, project performance.

INTRODUCTION

Defining the success of a project has always been full of ambiguity and there is no universal definition of success. McCoy (1986) observes that a standardized definition of project success does not exist nor is there an accepted methodology to measure it. The problem in the case of a construction project is compounded by the presence of different players (client, consultant(s), contractors), which have differing and at times conflicting objectives.

Success is viewed from different perspectives of individuals and the goals are related to a variety of elements including technical, financial, education, social and professional issues (Parfitt and Sanvido 1993; Lim and Mohamed 1999). Each industry, project team or individual has a definition of success. Failures and successes are relative terms and they are highly subjective (Parfitt and Sanvido 1993). Definition of success or failure can even change from project to project. Success for one participant may be a failure for another (Jha and Iyer 2004; de Wit 1988).

The perception of success or failure is also time dependent. The Denver airport project in the USA reveals that what was viewed as a failure during the construction phase is now treated as a success owing to high inflow of revenue and improved life style of local inhabitants (Griffith *et al.* 1999).

[1] knjha@civil.iitd.ac.in

Traditionally, project success is defined as the degree to which project goals and expectations are met and the project requirements are fulfilled and the project performance is evaluated using schedule, cost and quality performances, also known as the ‘iron triangle’ (Atkinson 1999).

Subsequently researchers have proposed different objective and subjective sets of project performance criteria in addition to the iron triangle. Some of the criteria used for evaluating the project performance are: perceived performance; client satisfaction; contractor satisfaction; project management team satisfaction; technical performance; technical innovativeness; efficiency of project execution; managerial and organizational expectations; personal growth; project termination; functionality; and manufacturability and business performance (Baker *et al.* 1983; Ashley *et al.* 1987; Freeman and Beale 1992). Further, a number of other studies have been conducted by different researchers who try to develop different frameworks for defining project performance parameters (Baccarini 1999; Songer and Molenaar 1997; and Chan *et al.* 2002). Some attempt has also been made to find the relative weight of the performance criteria. The studies, so far, have however neither tried to understand the inherent interrelationship(s) among the different performance criteria, nor tried to prioritize them scientifically.

OBJECTIVES

Based on the brief discussion above of the need to better understand the criteria affecting project success, the present study was carried out with a view to:

1. identify and rank the success criteria or parameters in a construction project;
2. better understand the role of individual criteria, and the interaction among them.

It is hoped that the results will throw new light on the prioritizing of activities of a project manager.

RESEARCH METHODODLOGY

As discussed earlier, several researchers have presented alternative criteria for evaluation of success of a construction project. From the different criteria already identified in published literature, a list of 22 criteria was drawn up on the basis a general agreement among professionals. This list was used to prepare a questionnaire to enable ranking of individual criteria. Responses to this questionnaire were obtained from 33 professionals in the Indian construction industry. The top 14 criteria were chosen for further analysis using interpretive structural modelling (ISM) and Micmac analysis. It may be noted that though these systems analysis tools have been relatively extensively used to analyse interrelationships among different variables in areas such as material management (Mandal and Deshmukh 1994) and supply chain management (Faisal *et al*. 2006), their use in the construction sector is not common. The ISM methodology (Sage 1977) uses the opinion of a group of experts to analyse the relationship between each pair of criteria and develop a model which shows the criteria arranged in a hierarchy showing their interrelationships. This enables practitioners to focus on key criteria. The Micmac analysis uses the same input as the ISM and classifies the criteria into groups depending on the driving power and dependence of each criterion. This classification could be very helpful to a project manager to understand the role of each criterion in terms of the overall success of the project.

RANKING THE PROJECT SUCCESS CRITERIA

Twenty-two project success criteria identified from a literature survey were used to develop a questionnaire. The respondents were asked to award a score to each of the criteria on a Likert scale of 1 to 5 corresponding to ‘Not at all important’, ‘Slightly important’, ‘Moderately important’, ‘Highly important’ and ‘Extremely important’, respectively. Questionnaires were administered personally to executives of construction firms and the responses were filled in the presence of the authors. A total of 33 responses were obtained in which 10% of the responses were from executives in the top management, 36% from middle management and 54 % from lower management. Out of the total respondents, 48.5% of the respondents had 11–20 years of experience and 15 % had more than 20 years. Further, 54% of the responses were from people working in the private sector, and the rest from government-controlled companies. Companies with more than 500 employees contributed 88% of the responses and 43% of the responses were from companies having more than US$200 million in annual sales.

The responses were analysed using SPSS, and the individual score for any criterion was determined as the average of all the 33 responses. The resulting scores for each of the 22 criteria are listed in Table 1. It may be noted that the maximum score for a criterion is 5.

Table 1: Ranking of project success criteria

Rank	Project success criteria	Code for reference	Mean score (scale of 1–5)	Remarks
1	Quality compliance	C_1	4.76	Considered ‘extremely’ important
2	Safety and health compliance	C_2	4.73	
3	Cost compliance	C_3	4.64	
4	Client satisfaction	C_7	4.61	
5	Profitability	C_5	4.42	Considered ‘highly’ important
6	User satisfaction	C_6	4.21	
7	Personal growth	C_9	4.15	
8	Efficiency of project execution	C_8	4.06	
9	Schedule compliance	C_4	4.03	
10	Organizational and managerial expectations	C_{10}	4.00	
11	Perceived performance and functionality	C_{11}	3.97	Considered important
12	Meeting technical performance and functionality specifications	C_{12}	3.91	
13	Reduction of disputes	C_{13}	3.67	
14	Contractor satisfaction	C_{14}	3.67	
15	Project management team satisfaction	C_{15}	3.48	Not considered for further analysis
16	Technical innovation	C_{16}	3.45	
17	Environmental sustainability	C_{17}	3.42	
18	Technical performance	C_{18}	3.42	
19	Functionality	C_{19}	3.33	
20	Preparing for the future	C_{20}	3.27	
21	Meeting design, functional, technical, managerial and organizational goals	C_{21}	3.12	
22	Project termination	C_{22}	2.48	

From Table 1 it can be seen that quality compliance, safety and health compliance, cost compliance and client satisfaction, having mean scores of 4.76, 4.73, 4.64 and 4.61, respectively, were identified as the most important factors defining success of a construction project. Given that these were the only factors scoring more than 4.5, they could be identified as ‘extremely important’. The appearance of criteria related to quality and safety with such high values is indicative of the changes in the priorities in the Indian construction scenario, which has been traditionally regarded as slack in terms of the importance accorded to these issues. Profitability, user satisfaction, personal growth, efficiency of project execution, schedule compliance and meeting organizational and managerial expectations are the criteria with mean scores between 4 and 4.5 and can be considered as the 'highly important' criteria. The criteria with mean scores between 3.5 to 4 are: perceived performance and functionality, meeting technical and functional specifications, reduction of disputes and contractor satisfaction. The remaining criteria (C_{15} to C_{22}) had mean scores ranging from 2.48 to 3.48 and were considered less important for further analysis and were dropped from the subsequent analysis. Hence, only the 14 criteria (C_1 to C_{14}) discussed above have been selected for further analysis since these are the most important criteria. A project's success or otherwise could be determined to a large extent by its performance in these 14 criteria and to a lesser extent in the remaining eight criteria. Further, keeping these eight criteria in the model development would have resulted in a large number of links and cross-links making it difficult to interpret.

INTERPRETIVE STRUCTURAL MODEL

Development of the model

ISM is a systems analysis tool used for identifying and summarizing relationships among specific variables that define a problem or issue or system (Sage 1977). It provides a means by which order can be imposed on a system. Therefore the 14 project success criteria are considered as the variables or components of a system whose output is a successful project. The technique is based on an analysis of interaction between variables in terms of a 'cause–effect' format, as identified by a panel of experts. In this case, a panel of three experts (different from the 33 respondents who scored the 22 criteria) were asked to opine on which of the following statements, referred to as V, A, X and O in further analysis, best define the relationship between any two criteria '*i*' and '*j*':

- criterion *i* helps meet criteria *j* (V);
- criterion *i* is helped by criteria *j* (A);
- criteria *i* and *j* help each other (X); and
- criteria *i* and *j* are unrelated (O).

For example the relationship between C_1 and C_{13} is defined as V which means that making efforts to meet project success criterion C_{13} helps meet project success criterion C_1 (see Figure 1). The relationship between C_1 and C_8 is defined as A which indicates that making efforts to meet project success criterion C_8 helps meet project success criterion C_1. It can be seen that the relationship between C_1 (quality compliance) and C_{14} (contractor satisfaction) is defined as X, which means that the relationship is both ways, that is making efforts to meet either of these criteria helps meet the other criterion. The relationship between C_9 (personal growth) and C_{14} (contractor satisfaction) is defined as O, which means that criteria C_9 and C_{14} are not related.

ISM methodology recommends the use of expert opinion to identify the relationship between the variables. This input of the experts has been summarized to form the that experts could obviously differ on their perception on the relationship between two criteria, and Figure 1 was drawn up on the basis of a majority opinion among the experts.

Code (*i*)	Performance criteria (*j*)												
	C_{14}	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8	C_7	C_6	C_5	C_4	C_3	C_2
C_1	X	V	X	X	X	O	A	V	X	O	O	V	O
C_2	V	V	O	O	V	O	A	V	O	V	O	V	
C_3	O	X	O	A	O	O	O	V	V	V	A		
C_4	V	X	O	O	V	O	X	V	O	V			
C_5	X	A	O	O	V	O	A	A	O				
C_6	O	O	A	X	V	O	O	X					
C_7	O	X	A	X	X	O	A						
C_8	V	X	X	O	V	V							
C_9	O	O	O	A	X								
C_{10}	X	X	A	A									
C_{11}	O	V	A										
C_{12}	X	V											
C_{13}	X												
C_{14}													

Legend:
V = criterion ‘i’ helps meet criterion ‘j’
A = criterion ‘i’ is helped by criterion ‘j’
X = criterion ‘i’ and ‘j’ help each other
O =criterion ‘i’ and ‘j’ are unrelated

Figure 1: Structural self-interaction matrix (SSIM)

The ISM software called ‘Concept Star’ from Sorach International has been used to analyse the SSIM data. Though the details have been omitted in this paper, it has been established that the model generated could have inconsistencies on account of transitive links (if A is related to B (A _ B) and B _ C, then A has to be related to C; or if A_ B and B is not related to C, then A cannot be related to C) (Sage 1977 and Sorach 1999). In this case also, the model generated was examined for inconsistencies by the authors using their experience, and ironed out using the ‘secondary links’ feature of the software. For example, the three experts have given a ‘V’ to the relationship between schedule compliance (C_4) and contractor satisfaction (C_{14}), as shown in Figure 1. ‘V’ means that meeting the schedule compliance criterion will help meet the contractor satisfaction criterion, but not vice versa. Hence the two are related. However owing to transitivity, the ISM software did not permit this relationship and this inconsistency was removed by introducing a link using the 'secondary links' feature of the software. The final model obtained is shown in Figure 2.

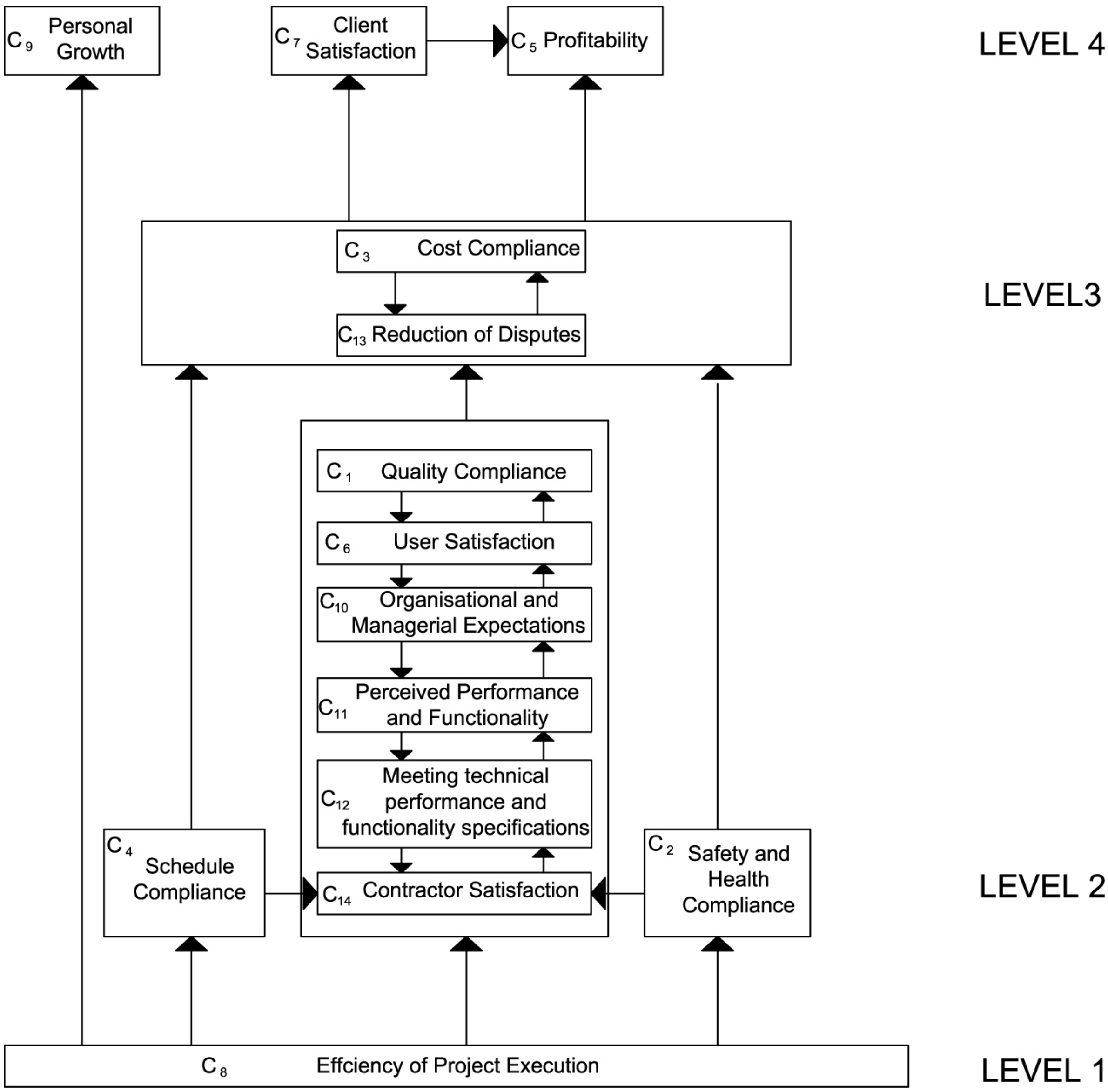


Figure 2: Interpretive structural model (ISM)

Analysis of the model

It can be seen from Figure 2 that the 14 criteria have been placed in a hierarchy, which places 'efficiency of project execution' at the first level, shown at the bottom of the figure, and also that this criterion is linked to all the other criteria. This finding can be taken to mean that focusing on this criterion helps meet all the other (success) criteria. Conversely, if the project execution is not managed efficiently, all other criteria are likely to suffer. In other words, a project management team efficiently executing the project gives maximum payoffs in terms of project success.

Eight of the 14 criteria (56%), fall in the second level, and if we include the first level criteria, and exclude personal growth (for reasons discussed later) then a substantial 69% of the criteria fall in the lower half of the model. This uneven distribution means that there are a larger number of success criteria that have to be addressed for the project to be considered a success. Six of the eight criteria in the second level are interrelated and hence the payoffs from taking measures to meet these criteria are likely to be more as compared to actions taken on schedule compliance and safety and health compliance. This does not however detract from the importance of these two criteria, it is just a question of relative gains.

Cost compliance and reduction of disputes are at the third level and they are affected by all the criteria discussed until now. Hence cost compliance and reduction of disputes will be achieved if attention is paid to the factors in the first two levels. These two criteria directly affect profitability and client satisfaction.

The criteria at the end of the hierarchy shown at the top of Figure 2 are profitability and client satisfaction, which can be taken to mean that these are most influenced by the other criteria and do not themselves influence any of the other criteria. In other words, so long as other criteria are appropriately addressed, profitability and client satisfaction are automatically taken care of. This can also be interpreted to mean that even by concentrating on other success criteria, a project management team can show results in terms of profitability and client satisfaction.

Figure 2 shows that there are three paths between efficient project execution and profitability/client satisfaction. The paths through schedule compliance and safety and health compliance are direct and hence more autonomous than the third path, since these two criteria do not interact with other criteria at the same level and they directly influence cost compliance and reduction of disputes. Hence, schedule compliance and safety and health compliance have less influence than the other six criteria in the second level. These six criteria that can be considered to be relatively more important are: quality compliance, user satisfaction, organizational and managerial expectations, perceived performance and functionality, meeting technical performance and functionality specifications and contractor satisfaction. Thus management will derive greater payoffs by focusing on these six criteria; however, it must be kept in mind that schedule compliance and safety and health compliance are important criteria, hence their presence in the second level.

Figure 2 also shows an interesting relationship between personal growth and the other criteria. This criterion is not linked to the system except for a dependence on efficiency of project execution. To that extent it can be identified as an autonomous criterion, which does not form a strong part of the system and does not directly affect any of the other project success criteria. Given the relatively high position of personal growth in Table 1 (score of 4.1), it can be stated that its importance lies as a motivational factor for the members to continue to strive for the success of a project.

MICMAC ANALYSIS

Micmac analysis (impact matrix cross-reference multiplication applied to a classification) (Arcade 2003) has been used to analyse and better understand the role of different components of a system. The Micmac analysis is an extension of the ISM in that it gives a numerical value to the strength of relationship between two variables or criteria. The criteria are analysed on two aspects. First, the number of criteria that the criterion under consideration affects; this gives its driving power or ‘influence’, i.e. its capability to influence other criteria. Secondly, the number of criteria that influence the criterion under consideration; this gives its ‘dependence’. The positions of the criteria are plotted on the influence–dependence map from which useful inferences can be drawn.

In the present study, the method was used to analyse the 14 criteria listed in Figure 1, and understand each of them in terms of their ability to influence others, be influenced by others, and so on. The analysis was carried out using the special Micmac software developed by ‘3IE’ (Institut d’Innovation Informatique pour l’Entreprise). The SSIM developed for the ISM analysis was used as the input data for the Micmac software.

Influence–dependence map

The results from the Micmac analysis are often presented in the form of an influence–dependence (I-D) map, and the individual points are plotted using the conventional x–y coordinate system. It may also be mentioned that conventionally, the map is divided into four quadrants, and the role of a particular criterion (or parameter) understood in terms of the position. This map obtained for the 14 criteria used in this study is shown in Figure 3. Now, given that the ‘dependence’ increases from left to right, and the influence increases from bottom to top, the area near the origin (the south-west quadrant) consists of points low on both scales and therefore those which can be considered as independent (or autonomous). Similarly, areas defined by the north-west and south-east quadrants are characterized by points with high influence with a low dependence and vice versa. These are sometimes also referred to as the influent and the dependent areas respectively. The north-east quadrant, comprising factors high on both dependence and influence, defines the so-called relay factors.

In the present study, based on the total score of each of the 14 criteria, the I-D coordinates were calculated and the criteria were plotted on the I-D map, as shown in Figure 3. This representation is discussed in greater detail below:

Influent factors

As mentioned above, these criteria in the north-west quadrant represent the subset that influences other criteria strongly, and depends little on them. ‘Efficiency of project execution’ occupies the position of highest influence and hence can be considered as the most important criterion. The other important factors since they are highly influent are: meeting technical performance and functionality specifications; quality compliance; schedule compliance; safety and health compliance and user satisfaction.

Relay factors

These factors, located in the north-east quadrant, have high influence and dependence, and need to occupy a high place in the decision-making process. Interestingly, the only criterion in this category in the present study is reduction of disputes. It can be well appreciated that reducing the disputes in a construction project will have far-reaching implications on the success of the project and hence the importance of this criterion. Indeed, the attention given by a construction company to reduction of disputes pays high dividends since it is both highly influential and is dependent upon other criteria.

Depending factors

Lying in the south-east quadrant of the I-D map these factors are more dependent and less influent. It may be noted that these factors could be called less critical from the point of view of decision making as they could be ‘taken care of’ if the factors that influence these are appropriately addressed. In the present study, as illustrated in

Figure 2, the criteria in this category are: contractor satisfaction; organizational and managerial expectations; client satisfaction and profitability.

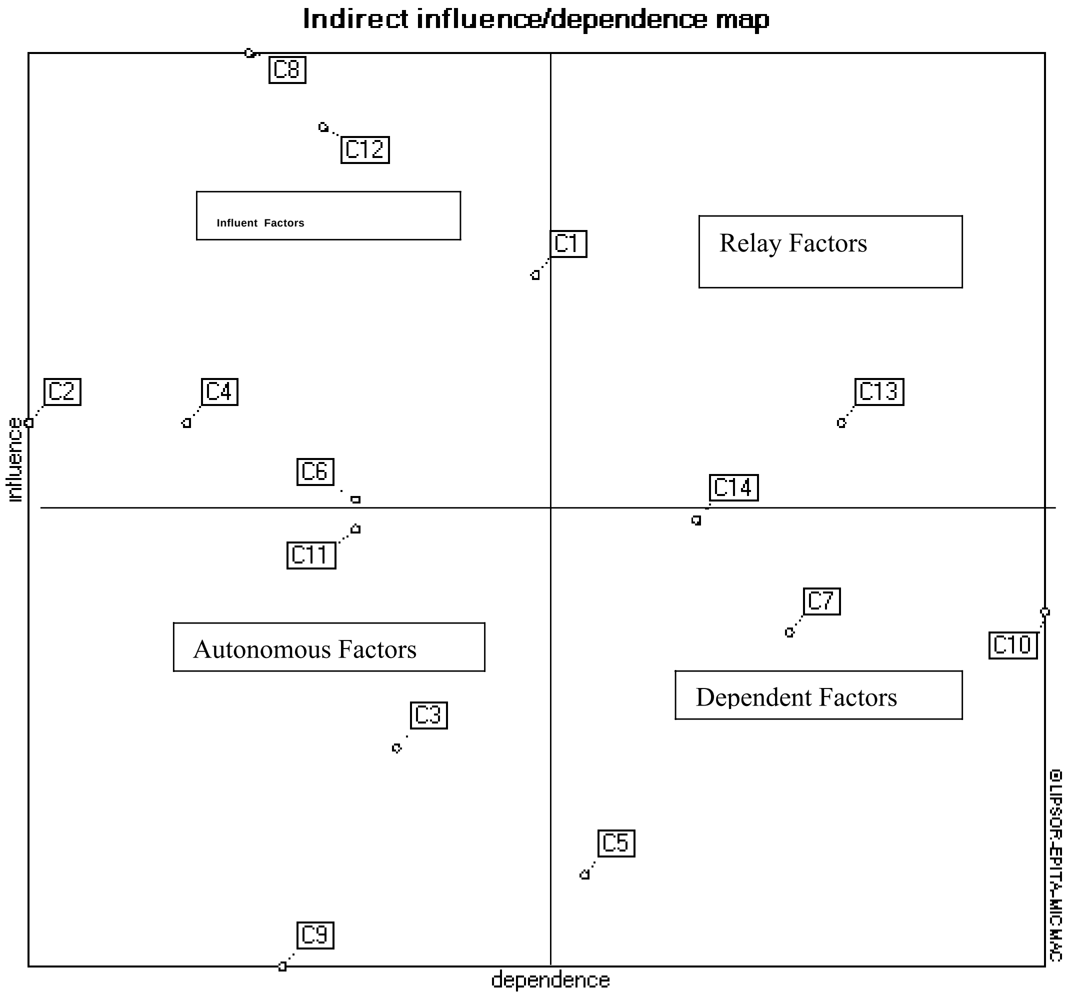


Figure 3: Indirect influence–dependence map

Autonomous factors

Factors located in the south-west quadrant are low on dependence and also influence – and could be looked upon as 'autonomous' or 'independent' in nature, and appear out of line with the system. Among the criteria in this part, a distinction is made between 'disconnected factors' and 'secondary levers', as discussed below.

Disconnected factors

These are situated near the origin and their evolution therefore appears to be excluded from the systems' global dynamics. Personal growth falls into this category, which is also brought from the ISM analysis mentioned above. In other words, it may be concluded that personal growth may not be specific to this system, i.e. project success, but is possibly a common requirement for all enterprises.

Secondary levers

These criteria are located above the diagonal and are more influent than dependent. These are, thus, not disconnected from the system and have some (albeit a low level of) influence on the other criteria. In the present study, perceived performance and functionality and cost compliance fall in this category.

It is clear from the methodology followed here, and that used in the Micmac analysis in general, that some issues could lie close to the borderlines of the quadrants, and thus such criteria need to be interpreted in a manner that they lie in a grey zone. For example in the present idea, C_1 lies on the border of the relay factors and influent factors and could therefore be a relay factor or an influent factor.

CONCLUSIONS

Twenty-two construction project success criteria were identified from published literature and later used in a questionnaire survey to determine their relative ranks. From this list, the top 14 criteria were identified and more rigorously analysed using interpretive structural modelling and Micmac analysis, which have been routinely used in the areas of material management and supply chain management though their application in the area of construction management is rare. Within the constraints of the questionnaire used and the analysis carried out in this study, the following conclusions can be drawn:

1. Efficiency of project execution emerges as a key success criterion having an influence on all the other success criteria under consideration.
2. Profitability and client satisfaction can be identified as criteria that are most influenced by others, and they themselves do not have an influence on the other success criteria.
3. Nine of the success criteria, that is 69%, are located in the first and second level of the model and six of them are interrelated. Hence construction project success requires attention to a large number of criteria, but the fact that six of them are interrelated spreads the effect of the efforts.
4. Personal growth is an autonomous factor that is not an intimate part of the system.

The findings of the paper can be useful to a project management team in focusing their attention on certain criteria with the tacit knowledge that some of the other criteria would then automatically be taken care of. In other words, the project manager can logically prioritize the criteria requiring attention.

REFERENCES

Arcade, J, Godet, M, Meunier, F and Roubelat, F (2003) *Structural analysis with the MICMAC method & actors' strategy with MACTOR method*. AC/UNU Millennium Project: Futures Research Methodology, available at www.acunu.org/millennium/FRM-v2.html.

Ashley, D, Jaselskis, E and Lurie, C B (1987) The determinants of construction project success. *Project Management Journal*, **18**(2), 69–79.

Atkinson, R (1999) Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management*, **17**(6), 337–42.

Baccarini, D (1999) The logical frame work method for defining project success. *Project Management Journal*, **30**(4), 25–32.

Baker, B N, Murphy, D C and Fisher, D (1983) Factors affecting project success. *In*: *Project management handbook*. New York: Van Nostrand Reinhold.

Chan, A P C, Scott, D and Lam, E W M (2002) Framework of success criteria for design/build projects. *ASCE Journal of Management in Engineering*, **18**(3), 120–8.

De Wit, A (1988) Measurement of project success. *International Journal of Project Management*, **6**(3), 164–70.

Faisal, M N, Banwet, D K and Ravi Shankar (2006) Supply chain risk mitigation: modelling the enablers. *Business Process Management Journal*, **12**(4), 535–52.

Freeman, M, and Beale, P (1992) Measuring project success. *Project Management Journal*, **23**(1), 8–17.

Griffith, A F, Gibson, G E, Hamilton, M R, Tortora, A L and Wilson, C T (1999) Project success index for capital facility construction projects. *ASCE Journal of Performance of Constructed Facilities*, **13**(1), 39–45.

Jha, K N and Iyer, K C (2004) Success of a construction project in Indian perspective. *In*: *Proceedings of International Conference and Exposition on Construction*, 23–25 September 2004, Construction Industry Development Council, 2, 90–8.

Lim, C S and Mohamed, M Z (1999) Criteria for project success: an exploratory reexamination. *International Journal of Project Management*, **17**(4), 243–8.

Mandal, A and Deshmukh, S G (1994) Vendor selection using interpretive structural modelling (ISM). *International Journal of Operations & Production Management*, **14**(6), 52–9.

McCoy, F A (1986) Measuring success: establishing and maintaining a baseline. *In*: *Proceedings Project Management Institute*, Montreal, Canada, 47–52.

MICMAC Structural Analysis, Laboratory for Investigation in Prospective Strategy and Organisation (LIPSOR), available at www.3ie.fr/lipsor_uk/micmac_uk.htm.

Parfitt, M K and Sanvido, V E (1993) Checklist of critical success factors for building projects. *ASCE Journal of Management in Engineering*, **9**(3), 243–9.

Sage, A P (1977) *Interpretive structural modeling: methodology for large-scale systems*. New York: McGraw-Hill.

Songer, A D and Molenaar, K R (1997) Project characteristics for successful public-sector design-build. *ASCE Journal of Construction Engineering and Management*, **123**(1), 34–40.

Sorach (1999) *Structured decision making with interpretive structural modeling (ISM)*. Ontario: Sorach Inc., available at www.sorach.com.

EXPLORING KEY ATTRIBUTES INFLUENCING CONSTRUCTION CLIENT SATISFACTION: A QUESTIONNAIRE SURVEY

Jianxi Cheng,[1] David Proverbs and Chike F Oduoza

School of Engineering and the Built Environment, University of Wolverhampton, Wulfruna Street, Wolverhampton, WV1 1SB, UK

Satisfying clients and creating a harmonized relationship amongst project participants can facilitate improved project performance and perceived success, and are thus critical for the existence and competitiveness of participants in the construction marketplace. However, client satisfaction as an important aspect of business remains an elusive issue to a majority of construction professionals. This research aims to explore key attributes influencing client satisfaction. The findings of a UK-wide questionnaire survey of public and private sector construction clients are reported. Descriptive data analysis is applied to investigate key aspects of client satisfaction. From the results, it is revealed that there exists a lack of clear understanding of the concept of client satisfaction. Clients' strategic decisions and their characteristics are found to have a crucial impact on their own satisfaction. The overall quality of services provided by service providers (consultants and contractors) plays a fundamental role influencing client satisfaction amongst other key attributes. Furthermore, the impact of strategic decisions on client satisfaction is shown to have strong links with different project stages. The results demonstrate that clients' optimum decisions and improved service quality from service providers can positively underpin project performance and lead to heightened client satisfaction and perceived project success. The findings will improve the understanding of the conception of client satisfaction and benefit both clients and their service providers.

Keywords: client satisfaction, performance, questionnaire survey, service providers, strategic decisions.

INTRODUCTION

In the construction domain, satisfying clients and creating a trustworthy and harmonized project relationship can facilitate improved project performance and perceived success and are thus critical for the existence and competitiveness of participants in the construction marketplace (Latham 1994; Egan 1998, 2002). Client satisfaction plays a fundamental role in determining the perceived success of a project and represents the bottom line of successful project implementation (Ashley *et al*. 1987; Bresnen and Haslam 1991; OGC 2002).

In the UK construction industry, however, client satisfaction has been a problematic issue for some considerable time (Banwell 1964; Latham 1994; Egan 1998; Egan 2002), and is an aspect of business that until now has been given little priority (Johnston 2004). Dissatisfaction is widely experienced by clients of the construction sector and may be caused by many aspects but is largely attributable to overrunning project costs, delayed completion, inferior quality and incompetent service providers

[1] j.cheng@wlv.ac.uk

including contractors and consultants (NAO 2000; HSE 2002; CJ 2004; WNSL 2006). Client strategic decisions also have a significant impact on their own satisfaction levels (Naoum and Mustapha 1995; Kumaraswamy and Dissanayaka 1998; Soetanto 2002; Cheng and Proverbs 2006). Decisions taken at earlier stages can significantly reduce costs and increase client satisfaction (Macmillan *et al*. 2001; Bartolo 2002). Poorly informed strategic decisions made by a client such as choosing a contractor without appropriate consultation or consideration could result in an under-performing project and ultimately cause client dissatisfaction.

However, the nature and significance of strategic decisions and their impact on client satisfaction has not been clearly identified and client satisfaction as an important aspect of business remains an elusive issue to a majority of construction professionals.

This research aims to explore key attributes influencing client satisfaction. The literature will be first reviewed and the client satisfaction phenomenon will be discussed. Descriptive data analysis is then applied on the results of a UK-wide questionnaire survey of construction clients so as to reveal the contributing key factors affecting levels of client satisfaction and seek improvement approaches.

CONCEPT OF CLIENT SATISFACTION

Satisfaction is difficult to define and there is little consensus towards its definition (Oliver 1981, 1997). The existing literature mainly focuses on the concept that the customer or client will make a comparison between the product or service and a certain standard (Smith 1969; Churchill and Serprenant 1982). If the outcome of a product or service meets or exceeds the customer’s expectation, satisfaction in general is achieved or exceeded (Locke 1970; Churchill and Serprenant 1982). The levels of satisfaction achieved or exceeded by the customer/client hence are dependent on the outcome of the comparison and the customer’s perceptive thinking. Hence, it is a highly subjective and complex matter that is challenging to measure reliably and objectively.

In the construction industry, there is a lack of clear understanding of the concept of client satisfaction (Cheng *et al*. 2006). The measurement of client satisfaction is often associated with performance and quality assessment in the context of products or services received by the client (Parasuraman *et al*. 1985, 1988; Soetanto and Proverbs 2004). Understanding of the clients and their business needs so as to help the industry to provide a better service to clients have always been the reason that the industry exists (Boyd and Chinyio 2006).

SATISFACTION ASSESSMENT

A number of models have been developed to facilitate the measurement of satisfaction such as SERVQUAL (Parasuraman *et al*. 1988; Siu *et al*. 2001), performance assessment (Soetanto and Proverbs 2004) and Business Excellence models (EFQM 2005; Cheng *et al*. 2005).

Several conceptual models have been developed based on the SERVQUAL principles to measure service quality and to reveal the interrelationship with client satisfaction in the construction industry (Hoxley 1998; Love *et al*. 2000; Siu *et al*. 2001). Client satisfaction is generally seen as the difference between perceived quality and actual quality performance and is related positively to service quality. However, the frame of reference or the standard of comparison used by clients to determine their satisfaction levels (Smith *et al*. 1969), have been somewhat ignored in these models and hence the applicability of these models to predict the levels of client satisfaction is limited.

Satisfaction measurement is regarded as an assessment of an internal frame of mind, tied to mental interpretations of performance levels. A client's internal frame of mind, mainly concerned with individual (i.e. the client) background, experience and perceptions, are likely to have an impact on the assessment of performance.

The EFQM (2005) Business Excellence model, which recognizes there are many approaches to achieving sustainable excellence in all aspects of performance, is a practical tool that can be used as a self-assessment tool or as a guide to identify areas for improvement.

Client satisfaction with the performance of their service providers including construction consultants (e.g. chartered surveyors, architects and engineers) and contractors on construction projects has been measured by assessing key performance indicators (KPI) in the UK construction industry (BSRIA 2003; RICS 2004; CE 2005).

The assessment of importance and performance of construction services issues were adopted by construction consultants to measure client satisfaction and address serious issues for their business excellence using client questionnaire survey approaches (Cheng *et al*. 2005). During which issues such as what levels of performance should consultants aim to achieve in order to satisfy their clients and what performance criteria should be prioritized so as to make most efficient use of resources and efforts in this regard can be addressed.

THE CLIENT SURVEY

In order to obtain reliable industry feedback in the context of investigating factors influencing client satisfaction, a UK-wide questionnaire survey of construction clients from both public and private sectors was conducted. A structured questionnaire was sent to each client.

Public sector clients, the largest client group in the UK construction industry, were chosen from the Municipal Year Book (MYB) (2006) which consists of all UK local councils and central government departments. Private sector clients were selected from the UK TOP 100 client list of the annual survey from the Building magazine (*Building* 2005), which represents a majority of the UK's private sector construction clients in terms of output.

The questionnaire was divided into three main sections, namely client characteristics, client strategic decisions at different stages and service quality of service providers, each of which containing a series of interrelated questions.

Each question required the respondents to provide a score against each of the two categories, the importance of the issue to the client and the performance (in the case of perception on services provided by service providers) or effectiveness (in the case of strategic decisions made by the client).

A five-point Likert scale from one (indicating the least effective/worst performance or least important) to five (indicating the most effective/best performance or most important) was adopted to measure respondents' attitude to the questions. It was adopted because the five-point Likert scale is simple to construct, likely to produce a highly reliable scale and commonly employed in the research field (Dawis 1987; Bernard 2000).

The questionnaire was designed as a research instrument to examine the impact of strategic decisions on client satisfaction within which factors influencing satisfaction levels were investigated, as developed in earlier satisfaction assessment models (Parasuraman *et al*. 1985; Soetanto and Proverbs 2004; EFQM 2005; Cheng *et al*. 2006). The performance criteria of consultant and contractors are defined as those used to measure the overall performance of the services based on the views of clients. The criteria were developed on the basis of the EFQM (2005) Business Excellence model and the results of a pilot survey of clients, supported by a literature review in the domain of performance and client satisfaction measurement (Cheng *et al*. 2005; Cheng and Proverbs 2006).

RESULTS

A total 800 questionnaires were distributed to pre-selected clients as sourced from the MYB (2006) and the Building's (2005) Top 100 clients list. 66 valid responses were received, representing a response rate of 8.3%, indicating a relatively good feedback from clients given the sensitivity of the data subject involved in the research.

Client characteristics

Table 1 demonstrates the client characteristics from the respondents.

About 80% of client individuals have more than 20 years' experience in construction, 90% of them hold medium or senior positions in their organizations and about 80% are decision-takers or approvers, indicating a majority of clients are experienced construction professionals who understand their organizations' decision-making mechanism and process (i.e. 44% of clients have worked in their current organizations for more than 10 years).

Public sector clients represent 87% of the respondents including central government departments, local governments and other public sector clients e.g. universities with private sector clients represent the rest of the respondents.

Building project (67%) is the predominant project type clients mainly procure, followed by infrastructure project (10%). Half of clients' projects are procured via traditional route, followed by Design & Build route (34%). However, only 3% of clients procure their projects via PPP/PFI route, reflecting a lack of understanding of and clients' reluctance to partnering procurement.

Although 47% of clients reported overrun project costs and 60% experienced delayed completion, clients still scored a highly satisfactory 4 (out of 5) for the overall quality of their projects, indicating that there exists a lack of clear understanding of the satisfaction concept.

It is suggested factors influencing client satisfaction are not limited to overrun costs and delays and there seems to be somewhat inconsistency of clients' perception on the assessment.

Table 1: Client characteristics

Description of clients characteristics	Criteria of measurement	Rate of responses (%)
How many years have you been involved in construction?	< 5 years	0%
	5-10 years	0%
	11–20 years	20%
	>20 years	80%
How many years have you been working in this organization?	< 5 years	32%
	5-10 years	24%
	11–20 years	33%
	>20 years	11%
What is your vocational background?	Architect	27%
	Designer/Engineer	30%
	Quantity Surveyor	13%
	Project Manager	13%
	Others	17%
Your position in your organization?	Senior (Directors)	43%
	Medium (Managers)	47%
	Low (Engineers)	10%
Which managerial role do you play in the project decision-making process?	Decision-approvers (e.g. main board members)	27%
	Decision-takers (e.g. senior managers)	53%
	Decision-shapers (e.g. expert focus group)	10%
	Decision-influencers (e.g. internal/external people who influence)	10%
The client organization:		
What type of organization are you?	Private sector	13%
	Central government	3%
	Local government	57%
	Other public sector	27%
	Others	0%
How many employees does your organization have?	< 10	3%
	11–50	16%
	51–249	7%
	250–500	27%
	>500	47%
Which construction sector does your organization mainly procure in?	Building	67%
	Infrastructure	10%
	Energy	3%
	Utilities	10%
	Others	10%
How many projects similar to the Case project type have you completed during the last ten years?	0	0%
	1-2	14%
	3-5	23%
	>5	63%
About the case project:		
What type of project is it?	Building	80%
	Infrastructure	14%
	Energy	0%
	Utilities	3%
	Others	3%
What procurement route did you adopt for this project?	Traditional	50%
	Design & Build	34%
	PPP/PFI	3%
	Management Contract	3%
	Others	10%

What type of contract does the project use	JCT	57%
	ICE	10%
	GC works	3%
	NEC	17%
	Others	13%
What are the original contract value and the outturn value (e.g. £ millions)?	Original value < Outturn value	47%
	Original value = Outturn value	43%
	Original value > Outturn value	10%
What are the planned and the actual duration from inception to completion?	Original value < Outturn value	60%
	Original value = Outturn value	30%
	Original value > Outturn value	10%

The analyses of importance and performance/effectiveness adopted the commonly used performance-importance approach by using average satisfaction scores (Martilla and James 1977; Soetanto 2002; Cheng *et al*. 2006). Average satisfaction represents the discrepancy between perceived levels of performance (P) or Effectiveness (E) and importance (I), that is, the subtraction of I from P (P - I) or E (E-I). The value of average satisfaction may be positive (indicating high levels of satisfaction but possibly excessive effort), zero (indicating optimally satisfied) and negative (indicating dissatisfaction).

Client strategic decisions

Clients were asked to give scores on how important and effective their strategic decisions are to the project/business. The importance factor represents clients' expectations on a particular decision issue and the effectiveness factor reflects clients' perception on the real effect of a particular decision made. Table 2 shows Effective Mean and Importance Mean and Satisfaction Mean scores with standard deviations which demonstrate the range of variation.

Table 2: Client strategic decisions at different project stages

Client strategic decisions	**Importance Mean (I)**	**Effectiveness Mean (E)**	**Satisfaction Mean (E-I)**	**Standard Deviation (SD)**
Pre-design stage	4.10	3.84	-0.26	0.9012
Decision of "Build/No build" after the project appraisal	4.47	4.33	-0.13	0.6182
Probable procurement method after decision of "Build"	4.27	3.93	-0.33	0.8300
Organizational structure	3.50	3.33	-0.17	0.9339
Work procedures	3.87	3.83	-0.03	0.7520
Consultants to be engaged	4.37	4.17	-0.20	0.7916
Other service providers to be engaged	3.80	3.77	-0.03	0.7746
Outline of project	4.00	3.60	-0.40	1.0796
Estimated costs	4.47	3.87	-0.60	1.0520
Review of procurement route	3.77	3.73	-0.03	1.0796
Details of project	4.23	3.90	-0.33	0.9866
Full development control approval	4.20	3.80	-0.40	0.8000
Co-ordination of elements of the project	4.23	3.80	-0.43	1.1160
Design stage	4.13	3.83	-0.30	0.9528
Information sufficient to obtain tenders	4.43	4.10	-0.33	1.0435

Balance required under the building contract	3.83	3.57	-0.26	0.8622
Tender stage	4.09	3.99	-0.10	0.9637
Documentation required for tenders	4.53	4.03	-0.50	0.8466
Identification and evaluation of potential contractors	4.30	4.03	-0.27	1.1528
Appointing the contractor	4.17	4.17	0.00	1.0328
Arranging site handover to the contractor	3.38	3.73	0.35	0.8226
Construction stage	4.19	3.68	-0.51	1.0907
Cost management strategy	4.59	3.93	-0.66	1.0796
People strategy	3.69	3.52	-0.17	0.8975
Settling the final account	4.29	3.59	-0.70	1.2949
Occupancy & Maintenance stage	4.09	3.76	-0.33	1.0413
Life cycle costing	4.07	3.66	-0.41	1.0520
Maintenance strategy	4.11	3.86	-0.25	1.0306
Disposal stage	3.02	3.04	0.02	0.7968
Demolition of project	2.89	3.00	0.11	0.8307
Transfer of project	3.15	3.07	-0.08	0.7630

DISCUSSIONS

Previous research indicated that the impact of strategic decisions on client satisfaction depends as much on timing as on the subject of the decision (Cheng *et al*. 2005; Cheng and Proverbs 2006). Client satisfaction, as a directly immeasurable subject, in fact is measured through the assessment of the service providers' performance and service quality (Cheng and Proverbs 2006). There exists a conceptual structure that indicates the influence of strategic decisions on client satisfaction and the correlation between them.

From the results, it is shown that clients in general are not satisfied with their strategic decision-making across a majority of project stages (e.g. Satisfaction Mean from -0.51 at Construction stage to -0.10 at Tender stage). Disposal stage is the only stage in which clients perceive the effectiveness of strategic decisions as satisfactory and strategic decisions have a positive impact on client satisfaction (SM=0.2;SD=0.7968).

Clients consider Build/No-build (I= 4.47), Procurement (I= 4.27) and Estimated costs (I=4.47) are the most important strategic decisions made at Pre-design stage. The results are consistent with previous research findings (Macmillan *et al*. 2001; Bartolo 2002; Soetanto 2002). The Effectiveness Means of the decisions are all above 4 (out of 5), indicating they are very effective decisions made by clients. However, the effectiveness of the decisions are not as high as clients expected i.e. client expectations are not being met, leading to slightly negative client satisfaction (SM= -0.13, -0.33 and -0.60 respectively). Standard Deviations suggest that clients in general are satisfied with their decisions.

The results indicate that effectiveness of client strategic decisions are not meeting clients' expectations and hence there may exist certain issues which need to be addressed properly during the decision-making and implementation process in terms of their effectiveness.

Service quality

Service quality is usually seen as an antecedent and pre-requisite of client satisfaction. Performance factors were assessed through a range of quality criteria involving key aspects of the services provided by contractors/consultants to clients (Cheng *et al*, 2006). Table 3 demonstrates clients' perception of satisfaction on services quality.

Table 3: Client satisfaction on service quality

Quality criteria	Importance Mean (I)	Performance Mean (P)	Satisfaction Mean (P-I)
Service delivery	4.12	3.90	-0.23
People of service providers	4.03	3.91	-0.11
Communications with clients	3.10	2.96	-0.14
Overall	4.00	3.80	-0.20

The results show that clients are slightly dissatisfied with the services they received from the service providers (SM= -0.20). However, the overall performance mean score achieved 3.80 (out of 5), indicating clients perceive a good service quality has been provided by their service providers (contractors/consultants).

Nevertheless, the performance mean score (3.80) is slightly lower than the importance mean score (4.00), suggesting clients' quality expectations are not being met by the performance of service providers who should seek improvement approaches to better satisfy their clients. Understanding client business and satisfying their needs are the key issues for service providers to address so as to improve their service quality (Ashley *et al*. 1987; Cheng *et al*. 2006). Improved service quality from service providers will positively underpin project performance and lead to heightened client satisfaction and perceived project success, which will benefit both of clients and their service providers.

CONCLUSIONS

In the construction industry, client satisfaction plays a fundamental role in determining the perceived success of a project.

From the results of a UK-wide survey of construction clients of public and private sectors, it is revealed that there exists a lack of clear understanding of the concept of client satisfaction. Client strategic decisions and their characteristics are found to have a crucial impact on their own satisfaction.

The overall quality of services provided by service providers (consultants and contractors) plays a fundamental role influencing client satisfaction amongst other key attributes. Furthermore, the impact of strategic decisions on client satisfaction is shown to have strong links with different project stages.

Improved service quality from service providers will positively underpin project performance and lead to heightened client satisfaction and perceived project success, which will benefit both clients and their service providers.

REFERENCES

Ashley, D B, Lurie, C S and Jaselskis, E J (1987) Determinants of construction project success. *Project Management Journal*, **XVII**(2), 69–79.

Banwell, G H (1964) *The placing and management of contracts for building and civil engineering work*. London: HMSO.

Bartolo, H M (2002) *Value by design: a qualitative approach*. CIB Report. UK

Bernald, H R (2000) *Social Research Methods: Qualitative and Quantitative approaches*. London: Sage Publishing.

Boyd, D and Chinyio, E (2006) *Understanding the construction client*. Oxford: Blackwell.

Bresnen, M J and Haslam, C O (1991) Construction industry clients: a survey of their attributes and project management practices. *Construction Management and Economics*, **9**, 327–42.

BSRIA (2003) Customer satisfaction service for M & E contractors: a proposal report, BSRIA website. Available online: http://www.bsria.co.uk/goto/content.asp?section=services&content=construction+practice&service=customer+satisfaction+research+for+m%26e+contractors&page=1&lang (accessed on 5 Feb 2005).

Building (2005) The top 100 clients in the UK survey. *Building*, 18, 58–9.

CE (2005) *Construction Consultants KPIs Handbook 2005*. UK: Construction Excellence.

Cheng, J and Proverbs, D (2006) Modelling strategic decisions and satisfaction: a conceptual model for construction clients. *In: Proceedings of World Conference for Accelerating Excellence in the Built Environment*, 2–4 October, Birmingham.

Cheng, J, Proverbs, D, Oduoza, C and Fleming, C (2005) A conceptual model towards the measurement of construction client satisfaction. *In:* F Khosrowshahi (Ed.) *Proceedings of 21st Annual ARCOM Conference*, 7–9 September, University of London. Association of Researchers in Construction Management, Vol. 2, 1053–62.

Cheng, J, Proverbs, D and Oduoza, C (2006) The satisfaction levels of UK construction clients based on the performance of consultants: results of a case study. *Engineering Construction and Architectural Management*, **13**(6), 567–83.

Churchill, G A and Serprenant, C (1982) An Investigation into the Determinants of Consumer Satisfaction. *The Journal of Marketing Research*, **19**, 491–504.

CJ (2004) Contract Journal web page. Available online: http://www.contractjournal.com/home/Holyrood building four months late and £30m over budget.htm (accessed on 4 April 2004).

Dawis, R V (1987) Scale construction. *Journal of Counselling Psychology*, **34**(4), 481–9.

EFQM (2005) European Forum for Quality Management (EFQM) web page. Available online: http://www.efqm.org/Default.aspx?tabid=35 (accessed on 5 May 2005).

Egan, J (1998) *Rethinking construction, The report of the Construction Task Force on the scope for improving quality and efficiency in UK construction*. London: Department of the Environment, Transport and the Regions.

Egan, J (2002) *Accelerating change, A Report by the Strategic Forum for Construction*. London: Rethinking Construction c/o Construction Industry Council.

Hoxley, M (1998) *The Impact of Competitive Fee Tendering on Construction Professional Service Quality, RICS Research Findings No. 24*. London: Royal Institute of Chartered Surveyors.

HSE (2002) *Train Derailment at Potters Bar 10 May 2002: A Progress Report by the HSE Investigation Board*, HSE interim report, end of June 2002.

Johnston, C (2004) From the client's perspectives. *Contract Journal*, 28 January.

Kumaraswamy, M M and Dissanayaka, S M (1998) Linking procurement systems to project priorities. *Building Research and Information*, **26**(4), 223–38.

Locke, E A (1970) Job satisfaction and job performance: a theoretical analysis. *Organisational Behaviour and Human Performance*, **5**, 484–500.

Love, P, Smith, J, Treloar, G and Li, H (2000) Some empirical observations of service quality in construction. *Engineering, Construction and Architectural Management*, **7**(2), 191–201.

Macmillan, S, Steele, J, Austin, S, Kerby, P and Spence, R (2001) Development and verification of a generic framework for conceptual design. *Design Studies*, **22**(2), 169–91.

Martilla, J A and James, J C (1977) Importance-performance analysis. *Journal of Marketing*, **41**(1), 77–9.

MYB (2006) *Municipal Year Book 2006*. London: Newman Books.

NAO (2000) *The Millennium Dome: Report by the comptroller and auditor general, HC 936 Session 1999-2000: 9 November 2000*. London: The Stationery Office.

Naoum, S G and Mustapha, F H (1995) Relationship between the building team, procurement methods and project performance. *Journal of Construction Procurement*, **1**(1), 50–63.

OGC (2002) Managing successful projects with PRINCE2. TSO.

Oliver, R L (1981) Measurement and evaluation of satisfaction process in retail setting. *Journal of Retailing*, **57**, 25–48.

Oliver, R L (1997) *Satisfaction: a behavioural perspective on the consumer*. New York: The McGraw-Hill Companies, Inc.

Parasuraman, A, Zeithaml, V A and Berry, L L (1985) A conceptual model of service quality and its implications for future research. *In: Managing Services Marketing*, London Business School, 122–35.

Parasuraman, A, Zeithaml, V A and Berry, L L (1988) ServQual: A Multi-Item Scale for Measuring Consumer Perceptions of Quality. *Journal of Retailing*, **64**(Spring): 13–40.

RICS (2004) Construction consultants key performance indicators, The Royal Institute of Chartered Surveyors (RICS) website. Available online: http://www.rics.org/Management/Qualitymanagement/Performancemeasurement/Construction+Consultants+Key+Performance+Indicators+Handbook+2004.htm (accessed 28 June 2005).

Siu, G, Bridge, A and Skitmore, M (2001) Assessing the service quality of building maintenance providers: mechanical and engineering services, *Construction Management and Economics*, **19**, 719–26.

Smith, P C, Kendall, L M and Hulin, C L (1969) *The measurement of satisfaction in work and retirement: a strategy for the study of attitudes*. California: Rand McNally & Company.

Soetanto, R (2002) *Modelling satisfaction for main participants of the construction project coalition: a study of mutual performance assessment*, Unpublished Ph.D. thesis, University of Wolverhampton.

Soetanto, R and Proverbs, D G (2004) Intelligent models for predicting levels of client satisfaction. *Journal of Construction Research*, **5**(2), 233–55.

WNSL (2006) Wembley National Stadium Ltd (WNSL) website, Wembley Stadium Update, 31 July 2006. Available online: http://www.wembleystadium.com/pressbox/pressReleases/julystatement (accessed on 31 July 2006).

THE INFLUENCE OF AN INFORMATION ENVIRONMENT ON CONTRACTORS' PERFORMANCE THROUGH IDIQ PROCUREMENT DELIVERY

Dean T. Kashiwagi[1]

Performance Based Studies Research Group, Arizona State University, PO Box 870204, Tempe, Arizona, USA

The motivation behind alternate delivery systems has been the poor performance of the traditional design-bid-build process. Construction professionals have identified public contract law and bureaucratic procurement/contract offices as one of the sources of problems in construction industry. The United States Army Medical Command (MEDCOM) (approximately $100M in construction renovation awards per year) attempted to overcome this obstacle through a partnership with the Performance Based Studies Research Group (PBSRG) at Arizona State University. The MEDCOM implemented the information environment portion of the Performance Information Procurement System (PIPS) into IDIQ contracts through the specifications. No procurement was conducted in the research and the concept has met with preliminary success, minimizing construction management issues by over 50%.

Keywords: best value procurement, construction performance, performance specification.

INTRODUCTION

The US Army Medical Command (MEDCOM) uses the Corps of Engineers (COE) contracting/procurement offices to deliver approximately $100M of construction per year (maintenance, repair, and modification). This is done through a delivery system called Indefinite Delivery, Indefinite Quantity (IDIQ). IDIQ is a system that pre-qualifies contractors before allowing them to compete for individual task orders. The advantage of the IDIQ delivery system is the time savings. Competing IDIQ contractors is far easier and involves a shorter time period than attempting to get a multitude of jobs through the traditional design-bid-build process (FAR 1997). The contractors can be selected by low price or the COE's best value process, which is heavily influenced by price. However, despite the flexibility the IDIQ system provided, the MEDCOM division was still unable to satisfy the programme demands.

The MEDCOM was introduced to the Performance Information Procurement System (PIPS) research, a best value approach to construction procurement, supported by the Performance Based Studies Research Group (PBSRG) at Arizona State University (ASU). The MEDCOM saw that the research provided results that supported the idea that theoretical concepts, processes, and structures based on leadership principles (accountability, alignment, performance measurement, and value-based), rather than management principles (control, direction, no performance measurements, and price-based), would optimize the delivery of construction (Kashiwagi *et al*. 2006) as well as

[1] dean.kashiwagi@asu.edu

the documented bureaucracy of the Corps of Engineers (COE) (Antonovich 1997; Putten 1999). The concepts included:

1. Minimization of data flow and necessary number of communications among participants.
2. Minimization of client documentation.
3. Outsourcing to the best value, considering cost and performance (past and present).
4. Utilization of a quality control (QC) plan as a selection criterion. The QC plan identifies the risk that the contractor does not control and defines how the contractor will attempt to minimize the risk.
5. By defining the risk that they do not control, the contractor has also defined what they do control (everything not listed as a risk that they do not control).
6. Also included in the selection criteria is a submittal of value added items identified by the contractor.
7. The contractor is able to use the QC plan and a risk management system to minimize change orders, quality issues and construction delays, due to risks that the contractor does not control.
8. Items or risks that the contractor controls are enforced by the design and specification.

This paper focuses on the implementation of best value concepts by the US Army Medical Command (MEDCOM), the results of the implementation, and potential of information environments in the delivery of construction and organizational efficiency. In the research, no procurement is performed, only the application of an information environment and the culture transformations that it requires.

BEST VALUE AT THE MEDCOM

MEDCOM noted the testing results of the Best Value/PIPS system over a 12-year period, and the validity they added to the research theory. Results included (www.pbsrg.com):

1. 440 tests on $480M of construction.
2. 98% performance (on time, on budget, meeting client's expectations).
3. Zero contractor generated cost change orders on 98% of the projects.
4. Construction management decline by as much as 80–90%.
5. Contractors profit increase from 5–20% and minimized fiscal risk on 100% of the projects

MEDCOM attempted to convince the COE to select IDIQ contractors and award task orders based on the following best value principles. Besides the theoretical best value concepts, the following was also requested:

1. Use past performance information without translation.
2. Use non-technical risk assessment/minimization and value added submittal.
3. Award a project based on price and performance. The performance should include the vendor's past performance; vendor's ability to identify, plan to

minimize, and prioritize project risks that they do not control; added value; and an interview. The proposed process to measure and compile the vendors' performance is illustrated in Figure 1. No qualifications should be considered.

4. Use a pre-award / quality control preplanning phase before the award.
5. Implement the quality control plan into the contract and force the contractor to self manage their project based on risk by using a weekly risk report that would only document cost, time and quality risks.
6. Use an information environment that minimizes the flow of information, moves the critical information to the right place in the shortest period of time, and forces the source of risk or non-performance to be accountable (Sullivan *et al*. 2006).

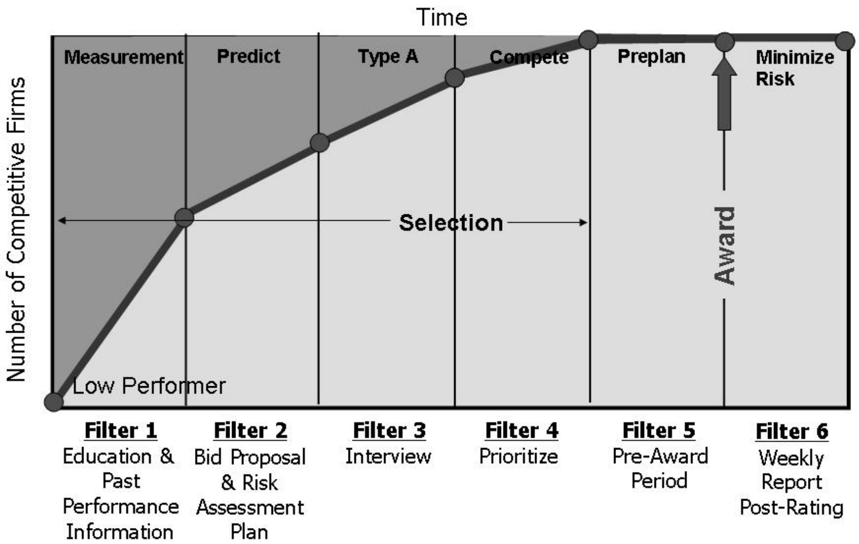


Figure 1: Performance information procurement system (pips) filters: a best value process for measuring vendor performance (Kashiwagi 2004)

The attempt was unsuccessful. The COE decided there were too many changes and believed that some of the changes were not legally allowed (this is a point of disagreement between several COE agencies). Some of the changes/ misunderstandings included:

1. The COE were under the misunderstanding that the process was proprietary and that Arizona State University (ASU) would be running their procurement. It is illegal for the COE to outsource its procurement (FAR 2002).
2. The COE felt that non-COE personnel could not be on the selection team.
3. The Army Federal Acquisition Regulation (AFAR) would not permit the use of weights and numbers in a best value selection (FAR 2002).
4. The pre-award phase – where the best value contractor creates their quality control (QC) plan, quality assurance (QA) checklist and schedule – was not allowed by the Federal Acquisition Regulation (FAR), due to the requirement to have discussions with all the offerors before the award of the contract (FAR 2002).

5. The existing COE quality assurance plan was verification of the technical requirements, while the QC plan for the Best Value/PIPS was to minimize risk that the contractor did not control.

The above points of resistance were either misunderstandings or items that could easily be adapted to ensure regulation compliance. However, current Director of the Facility Life Cycle Management Division at MEDCOM, realized that the cultural change required to implement Best Value/PIPS in the COE was too drastic, and he proposed to obtain higher performance results another way. With assistance from the Performance Based Studies Research Group, the Director of MEDCOM proposed to overcome the COE's resistance to change and policies by using the theoretical concepts of a best value environment as a component of the technical requirements/specifications of the IDIQ contract that the COE would award to the IDIQ contractor. The Director proposed that the best value environment and an information environment as presented by Kashiwagi (2004), were the same, and therefore was specifiable. In other words, the Director of MEDCOM proposed that instead of forcing the COE to change its Best Value procurement process to procure services from higher performing IDIQ contractors (by definition: efficient, experienced, capable of being on time, minimize risk and change orders, and meet the client's expectations), that the best value practices/information environment could be made a requirement in the specifications. This would force contractors who won the COE awards to comply with the best value practices of a high performing contractor. This hypothesis makes one of the following assumptions:

1. A lower performing contractor can become a high performer by using a best value/information structure.
2. A contractor who competes on a specification that requires them to report the delivering of construction through a best value/information environment structure will educate/train their personnel to act in a manner to deliver performing results.
3. An information environment forces accountability regardless of the selection process.

The Director of MEDCOM proposed that in order to test the hypothesis over three years, the following items would be measured:

1. The number of projects where the source of the problem was not immediately identifiable.
2. The number of projects where the source of the problem was the contractor.
3. The number of projects where (if the source of the problem was the contractor), the contractor would not immediately take action at their own expense to solve the problem.
4. The number of projects that were completed by the same contractors, before the integration of the best value environment, where problems could have been solved by the best value environment.
5. The interest of the contractors to learn the process, and implement training programmes in their companies.
6. The number of companies that would take the programme to other clients.

The current estimate of the number of projects with performance issues is 15 (out of 150) or 10%. Out of the projects with performance issues, only 5 (3.3% of total) are due to the contractor.

THEORETICAL FOUNDATION OF BEST VALUE/ PERFORMANCE INFORMATION PROCUREMENT SYSTEM (PIPS) PROCESS

The approach of the US Army Medical Command (MEDCOM) included an understanding that the Corps of Engineers (COE) used a price-based construction/services environment (Kaji 2006.) By comparing the price based and best value environments, the MEDCOM identified the following characteristics and assumptions of the price based environment (Kashiwagi 2004):

1. Construction services were considered a commodity.
2. The Client's design personnel could direct, manage, and inspect the commodity contractors to deliver an acceptable product using minimum standards, details and an overall design.
3. The best price was the lowest price (because the contractors were all the same).
4. The contractors were being asked to deliver a product based on the minimum requirements.
5. The client's representatives were the experts in terms of identifying "acceptable" quality.
6. The process does not give credit to the highly trained craftsperson, and may have a detrimental effect on the number of skilled craftspeople, the level of quality of those who remain in the industry, and the ability of the industry to quality control their own work.
7. The client's representative directs the contractor and their personnel.
8. The process requires more people than the best value sector where the best value contractor uses their most highly skilled craftspeople.
9. Because the design /specifications are shaped by technical specifications, the quality of work is the minimum and always has a downward movement.
10. The process requires more experts, more direction, more inspection, and more confusion on what is the best quality.
11. With one party doing the work, and one party controlling the work (through management, control, inspection and direction) the amount of communication/data flow is increased.

When compared to the best value environment, confusion in the price based environment is increased simply as a result of an increased number of individuals (managers, inspectors, experts, designers, clients). The confusion results in a need for more management/inspection to sort out the confusion. In the confusion, no one is accountable, forcing every participant to protect themselves before thinking in the best interest of the client or the organization that the individual is employed by. The authors propose this condition as the definition of a bureaucratic environment. It is easier to point fingers and require an individual to show that another entity did not follow rules than it is to identify the solution. The rules become the defence for the bureaucratic action. This causes a bureaucracy, where several organizations are involved, and in each organization, the individuals representing the organization are acting in their own best interest. This is the cycle of bureaucracy (Figure 2).

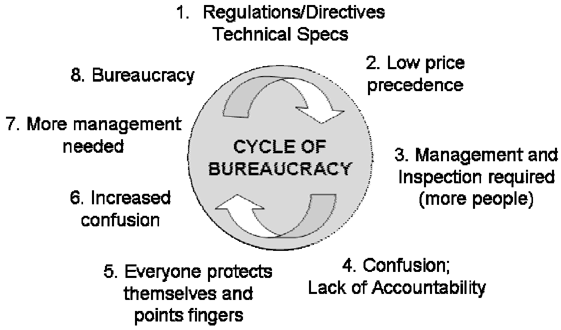


Figure 2: Cycle of bureaucracy

A contribution of the authors is the understanding that bureaucracy:

1. Happens in all organizations at various levels.
2. Happens between organizations.
3. Happens with every individual who works in a bureaucratic environment.
4. When the client forces the vendor to act defensively, the client and the vendor's personnel, and all other participants become bureaucratic.
5. Bureaucracy is created by a price based market structure, a lack of information and fear.

The authors hypothesized that an information environment specified in the specifications would mimic a best value environment without altering the procurement system. The authors further hypothesized that the contractors would understand that an information environment would maximize their efficiency and profit, and therefore be in their own best interests. This realization coupled with the information environment would increase the performance of the IDIQ contractors. The Director of MEDCOM requested that the Performance Based Studies Research Group at Arizona State University (ASU) set up an information environment in the IDIQ contract where performance metrics would be constantly measured. The goal was to create a best value information environment, embed within the technical specifications like a Trojan horse within the COE bureaucracy, and then to measure the results. Through measurement, accountability would be realized and the information environment would in essence encourage the contractors to improve and perform. The environment would make every participant accountable, as all would be measured (contractors, MEDCOM personnel, COE personnel, etc.). Performance-based specifications have been proposed before (FAR 1997); however, simultaneously using specifications with minimum standards, best value concepts, and an information environment, is a new contribution to the delivery of construction.

THE MEDCOM BEST VALUE/INFORMATION CONCEPTS/ENVIRONMENT AND TEST RESULTS

The MEDCOM decided to incorporate the following into their specifications:

1. Checklists that forced the use of preplanning and a quality control plan that minimized the risk that the contractor did not control. These checklists applied to both the design stage (work plan) and the construction stage.
2. The use of a quality control plan (focused on risk identification and minimization), a quality assurance checklist, a schedule and a weekly reporting system tracking the risk that the contractor did not control.

The MEDCOM then used the information system to compile multiple weekly risk reports and develop current performance barcodes or measurements for the entities involved. Performance measurements were computed for the contractors, as well as the COE project managers, the MEDCOM project integrators, and the procurement offices.

The key component of the best value environment uses the concept from the Information Measurement Theory (IMT) asserting that an individual who is experienced and understands the system can (Kashiwagi 2004):

1. Identify what they are responsible, and what others are responsible for.
2. Understand that the greatest risk comes from parties who they have no control over.
3. Understand that while an individual can only control themselves, they must understand the role of others in order to minimize risk through simple coordination/ communication.
4. Act as a team player and facilitates a “win-win” with those they work with.
5. Minimize risk that they do not control and no sharing of risk, just allocation.

There are four key components to the information system. First, the contractor is asked to separate the risks they control from those that they do not by identifying the latter. The contractor is then told that whatever is not on the QC plan (risks that they do not control), is risk that they do control (except for unforeseen risks). The contractor is then directed to identify how they will minimize the concerns or risks. The authors are making the assumption that it is much easier to have the contractor identify risks to the project that they do not control, than it is to identify all the risks that the contractor does control. It also transfers the risk to the contractor by having the contractor identify the risks. The authors are also assuming that a non-experienced contractor cannot as efficiently identify the risks that they are not responsible for. This is because (Figure 3):

1. Experienced contractors know the roles and impact of different participants.
2. Inexperienced contractors are reactive, and only know their risk in terms of what they are supposed to do.
3. Experienced contractors do not need to be managed and directed.

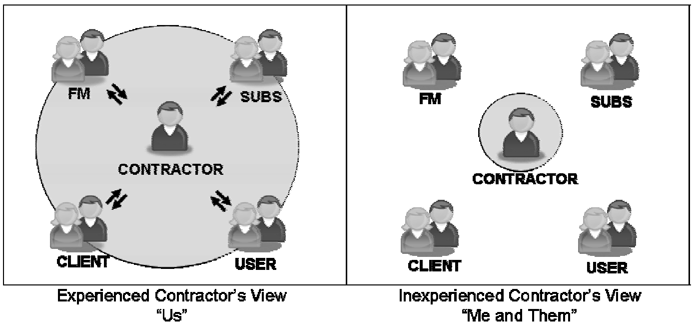


Figure 3: Experienced vs. non-experienced "sphere of perception"

The second key component is to make it a requirement that the vendor/contractor minimizes risk that they do not control. If they execute their risk minimization steps, and are not able to minimize the risk, the risk will be placed on the weekly report which identifies:

1. Why the contractor was not able to minimize the risk.
2. What or who is the source of the risk.
3. What needs to be done by the source of the risk to minimize the risk.
4. What the impact to the project will be in terms of time, cost, and expectation.

The third concept is that it is by contract, and in the best interest of the contractor, to report the risk on the weekly report (Figure 4.1–4.4). The QC plan, QA checklist and weekly report protect the contractor. All documents identify the risks that the contractor does not control and, by definition, protects the performing contractor. The weekly risk report is sent to the COE PM, but also is directly inserted into a system that compiles the information from all MEDCOM projects into a Director's Report that identifies:

1. The top ten projects that bring the greatest risk.
2. Relative performance numbers of the contractors and client representatives involved.
3. Identification of the relative performance of the contractors' critical personnel and subcontractors.
4. Performance of the client's organization in delivering construction services.

The fourth concept is that the contractor is rated on the finished project, and that rating becomes 50% of their future performance rating. All key individuals on the project and critical subcontractors also receive the same rating.

PRELIMINARY TEST RESULTS

The MEDCOM performance before the test was run included:

1. A problem a day floated up through the bureaucracy and was presented to the MEDCOM construction manager.
2. 50% of the projects are on time, and on budget.
3. Contractors on 80% of the projects do not preplan and minimize risk.
4. None of the contractors had a QC plan that protected themselves and the clients.

5. 25% of the projects are delayed and the reason is unclear.
6. None of the contractors had their own QC plan, QA checklists and weekly risk report.
7. No contractors came to the annual training at ASU seeking education.

The information environment was initially pilot tested on six projects (no procurement was performed, only application of the information environment) and within eight months it was expanded to encompass 87 projects. In the past year, it has been implemented on all projects with a budget value greater than $300,000 (USD), which, is at the time of publication, 189 projects with a construction value of over $289,000,000 (USD). In summary, the current estimate of the number of projects with performance issues is 15 (out of 189) or 8%. Out of the projects with performance issues, only five (2.6% of total) are due to the contractor. Other results include:

1. 99% of projects currently on budget (no contractor changes to budget).
2. Average contractor budget increase is .03%.
3. 95% of projects currently on time (no contractor changes to schedule).
4. 9.8 owner satisfaction on completed projects (1–10 scoring, 10 being the highest).

Figure 4 displays the results of the Information Environment. Figure 4.1 shows the overall output of the construction delivery. Figure 4.2 shows the overview of a project showing client and contractor generated risks. Figure 4.3 shows the top ten risk projects. Figure 4.4 shows the differential of the contractor performance. However, any entity's performance who is involved in the project can be compared (COE, PM, PI, etc.). Once the project is finished, the project is rated and modifies the new contractor performance line.

There has been a change in attitude of the contractors. In the first year when the contractors were exposed to the process, none of the contractors expressed an interest in an education of the process or running the process except through forced tests. The second year, four of the six contractors invested in further education of the process.

In the third year:

1. Three contractors invested heavily into education of their personnel.
2. All six contractors spent additional time with MEDCOM personnel learning about the system.
3. All six contractors are attending the annual education/training at Arizona State University at their own expense.
4. One of the contractors is bringing other clients to the training, encouraging them to use the Best Value approach.
5. All contractors are sending in the weekly reports that generated the performance/ risk information.

DIVISION OVERVIEW	11/03/06
Total Awarded Budget	$172,751,944.23
Current Cost	$174,484,794.47
Over Budget	$1,732,850.24
PROJECT OVERVIEW	
Total Number of Projects	116
% Projects On Time	85%
# of Jobs Delayed	17
% Projects On Budget	86%
# of Jobs Over Awarded Budget	16
# of Projects Missing Owner Ratings	0
AVERAGE PROJECT	
Project Budget	$ 1,489,240.90
# of Risks per Job	3.14
Owner Generated Risks	1.66
Number of overdue risks	0.25
% Over Awarded Budget	3.39%
% over budget due to owner	3.23%
# of Days Delayed	8.76
# of days delayed due to owner	7.62
Owner Rating	9.17
Risk Number	**2.42**

UNFORESEEN (UF) & OWNER (O) RISK	
# UF Risks affecting budget/schedule	0
Days Delayed (Calendar)	0
Additional Cost	$ -
# O. Risks affecting budget/schedule	1
Days Delayed (Calendar)	0
Additional Cost	$ 2,000.00
Above risks include both potential and resolved.	
CONTRACTOR RISK	
# of Unaddressed/Overdue Risks	1
# Unrated Risks	0
# Risks affecting budget/schedule	2
Risk to Schedule (calendar days)	15
Risk to Cost	$ 1,000.00
Contractor Satisfaction Rating	**10.0**
Above risks include both potential and resolved.	
OVERALL CURRENT STATUS	
Days Delayed (Calendar days)	5
% Delayed	0.8%
Contractor % Delayed	0.8%
Additional Cost	$ 2,000.00
% Over Award	9.2%
Contractor % Over Award	0.0%
Project Satisfaction Rating	**10.0**
Risk Number	**1.16**
Above Schedule and Budget additions include only resolved risks.	

4.1 Overall organization performance

4.2 Individual project performance

TOP 10 RISK RANKING PROJECTS			
No.	**Project**	**Location**	**Risk #**
1	WP Fire Protection Upgrade	Fort Knox, KY	12.71
2	Renov. Team Ctr.& P.L. Recovery	Fort Lewis, WA	11.60
3	Outpatient Clinic	Fort Campbell, KY	10.78
4	Construct Hyperbaric Chamber	Fort Gordon, GA	10.46
5	Smith Dental Clinic	Fort Carson, CO	10.11
6	Repair/Renovate DC #4	Fort Campbell, KY	9.86
7	Renew Health Clinic, Bldg 422	Presidio of Monterey, CA	9.44
8	Replace Signage	Fort Rucker, AL	9.17
9	Replace Signage	Fort Rucker, AL	9.17
10	Renew Dental Clinic #3	Fort Lewis, WA	8.21

CONTRACTOR OVERVIEW	Contractor A	Contractor B	Contractor C
Total Awarded Budget	$15,725,858	$52,274,179	$ 2,885,433
Current Cost	$16,480,244	$52,274,179	$ 2,885,433
OVERVIEW OF PROJECTS			
Total Number of Projects	25	18	6
# of Jobs Delayed	4	2	4
# of Jobs Over Awarded Budget	9	0	0
AVERAGE PROJECT			
% Over Awarded Budget	13.93%	0.00%	0.00%
# of Days Delayed	6.84	2.33	9.50
Owner Rating	8.03	8.89	10.00
Risk Number	**4.15**	**2.94**	**2.41**

4.3 Risk ranking of projects

4.4 Comparing vendor performance

Figure 4.1–4.4: Results of an information environment

Other preliminary results include:

1. Projects *started* with the best value environments have had no outstanding issues where the contractor is at fault.
2. The information system has quickly identified that the biggest source of risk is the client and procurement/contracting offices.
3. There have been no disagreements or arguments over who is the source of risk that is identified by the process.
4. Contractors are slowly learning about minimizing risk that they do not control.
5. Meaningful quality control plans have been a challenge.
6. The contractors and users have had a difficult time understanding the connection and use of the QC plan, QA checklist and the weekly report.

CONCLUSION

The authors proposed that an information environment can be directed into the technical specifications without changing the procurement system and force best value practices. This hypothesis is dependent on the contractor using a QC plan that minimizes risk that they do not control. The use of the QC plan, QA checklist, weekly risk report and information environment director's report, all of which are documented by the contractors, has provided MEDCOM with an accurate performance history of construction projects on a weekly basis. Preliminary results indicate that the more efficient environment has maximized the profit of the contractors (Welker 2007). Most of the projects are still in the design phase, and construction results will be forthcoming.

REFERENCES

Antonovich, M D (1997) A Bureaucratic 'Rain' of Terror. *National Wildlife Magazine*. Available online: http://antonovich.co.la.ca.us/pressrel/2/pasgop.htm (accessed on 1 January 2007).

Federal Acquisition Regulations (FAR) (2002) 15.306(d)(1) and (e)(1). Available online: http://www.arnet.gov/far/ (accessed 1 January 2007).

Federal Acquisition Regulations (FAR) (2002) 37.204. Available online: http://www.arnet.gov/far/ (accessed 1 January 2007).

Federal Acquisition Regulations (FAR) (2002) 15115.304. Available online: http://www.arnet.gov/far/ (accessed 1 January 2007).

Federal Acquisition Regulations (FAR) (1997) Best Practices for Multiple Award Task and Delivery Order Contracting, Interim Edition. Available online: http://www.whitehouse.gov/omb/procurement/interagency_acq/best_practices_multiple_award_task_contracting.html (accessed 1 January 2007).

Kaji, M (2006) Doing Business with the US Army Corps of Engineers. *In: 4th Annual DOD Hawaii Small Business Forum*, 30 May 2006, Honolulu, HI.

Kashiwagi, D T (2004) *Best Value Procurement*. Tempe, AZ: Arizona State University.

Kashiwagi, D T, Sullivan, K, Kashiwagi, M, Chong, N and Pauli, M (2006) Reduced Information Flow Maximizes Construction Performance. *In: International Conference in the Built Environment in the 21st Century (ICIBE 2006)*, 13–15 June 2006, Kuala Lumpur, Malaysia.

Putten, M V (1999) National Wildlife Introduction. *National Wildlife Magazine*, Feb/Mar, **37**(2).

Sullivan, K, Kashiwagi, M, Badger, W, Kashiwagi, D T, Egbu, C and Chang, C (2006) Leadership, the Information Environment, and the Performance Measuring Project Manager. *In: Association of Researchers in Construction Management (ARCOM) 23rd Annual Conference*, 4 September 2006, University of Central England, Birmingham.

Welker, R (2007) *Performance Based General Contractor, Best Value / Leadership Conference Presentation*, Arizona State University, Chandler, Arizona.

IMPROVING SATISFACTION WITH CONSTRUCTION PROJECT OUTCOMES: THE ROLE OF CULTURE

Nii Amponsah Ankrah,[1] David Proverbs[1] and Debrah Yaw[2]

[1]*School of Engineering and the Built Environment, University of Wolverhampton, Wulfruna Street, Wolverhampton, WV1 1SB, UK*
[2] *School of Business and Management, Brunel University, Uxbridge, UK*

The quest to evolve an industry that performs well requires an evolution of the process of delivery. To this end, new approaches such as lean thinking and partnering have been introduced into construction. Underlying many of these new approaches is a need for fundamental changes in the culture within the construction project organization. Many have thus called for cultural change on construction projects. In order to establish which dimensions of culture need to be changed, and the direction of such change, this research was undertaken to look for empirical evidence that such changes will lead to performance improvement. The satisfaction of participants with project outcomes was measured as a proxy for performance. Data on cultural orientations and satisfaction levels was collected through a questionnaire survey of UK contractors. Although factor analysis revealed five principal dimensions of culture – workforce orientation, performance orientation, team orientation, client orientation and project orientation – only team orientation and workforce orientation were found to lead to improved satisfaction. It is recommended therefore that more effort and resources are devoted towards improvements in these regards.

Keywords: construction project organization, organizational culture, participant satisfaction, team orientation, workforce orientation.

INTRODUCTION

The extent to which a construction project is delivered to the satisfaction of stakeholders is contingent on a number of factors. One of these factors is the process employed in delivering the project. When the process goes wrong, built facilities may end up defective, over-budget, late, aesthetically, environmentally, and functionally inadequate, with huge operating costs, and participants in litigation, leading to stakeholder dissatisfaction. The quest for improvement thus requires an evolution of the process of delivery (Riley and Clare-Brown 2001). To achieve this evolution, various ideas such as lean thinking, partnering and supply chain management have been introduced into construction. Underlying many of these new approaches is the need for a fundamental change in the attitudes of participants, nature of relationships between project participants, and their approaches to work. Many have therefore called for a change in the culture of the industry (cf. Egan 1998), and this study was undertaken to empirically determine which dimensions of culture need to be changed, the direction of such change, and the consequences for performance and satisfaction of project participants.

[1] nii_a_ankrah@yahoo.co.uk

WHAT IS CULTURE?

Culture has over 164 definitions (Allaire and Firsirotu 1984) reflecting very divergent views, and also reinforcing the view that the concept of culture exists in a constant state of change. The first use of the term in its true anthropological sense is attributed to Edward Tylor who defined culture as “that complex whole which includes knowledge, belief, art, morals, laws, custom, and any other capabilities and habits acquired by man as a member of society” (Rooke 2001). More detailed reviews of some of the various concepts of culture are presented in Keesing (1974), Smircich (1983), Allaire and Firsirotu (1984), and Ankrah and Proverbs (2004). Common themes running through many definitions are that culture is learned and shared, determined by contextual factors, with common underlying basic problems, and shapes attitudes, perceptions and behaviours (Ankrah and Proverbs 2004). From this, culture may been defined as that unique configuration of solutions – embodied in attitudes, behaviours and conditions – that a construction project organization and its members adopt in dealing with various organizational problems at the project level.

The culture of the construction project organization and project delivery

According to Newcombe (2003), the stakeholders within the construction project organization (CPO) interact with the project in two primary arenas; cultural and political, with the cultural arena represented by the ideology or shared values of the project participants. It is believed that the project-based arrangements that characterize the production of the built environment make the potential impact of culture even more pronounced than in other industries (Ofori 2000). The culture of the CPO is often associated with such attributes as fragmentation, antagonism, mistrust, poor communication, short-term mentality, blame culture, casual approaches to recruitment, machismo and sexism (Egan 1998; Dainty *et al.* 2002; Serpell and Rodriguez 2002). These attributes are in turn associated with project outcomes like litigation, poor health and safety performance, and inferior quality.

Whilst such associations are helpful to the extent that they focus attention on the failings of the industry, and point to aspects that need to be improved, they are sometimes arbitrary and often based on no more than anecdotal evidence, and as such do not provide a useful systematic basis for assessing the real impacts of culture. This suggests the need for systematic empirical research. Some researchers who have attempted to examine some of these associations include Fenn *et al.* (1997), Soetanto *et al.* (1999), Cooper (2000), Ngowi (2000), Thomas *et al.* (2002) and Phua and Rowlinson (2003). This research seeks to carry forward this research agenda but focusing on participant satisfaction.

Diagnosing culture

An assessment of culture requires the identification of aspects important to culture (Hofstede 2001). Such aspects are typically referred to as *dimensions* of culture. Various dimensions have been advanced for studying culture and many of these are catalogued in Ankrah *et al*. (2005). However, within the context of the construction project, it has been argued *ibid* that some of these dimensions are inappropriate. To identify which dimensions are most relevant within a construction project context, these dimensions need to be considered in the light of the unique problems of the construction industry. The problems of the construction industry are well documented, and nowhere better articulated than in the major construction industry reports that have been published since the Simon (1944) report. All these reports have examined the problems of the construction industry and have in the main recounted the same industry failures time and time again. In trying to identify relevant dimensions for this research based on the construction industry's problems, the landmark Egan (1998) report was consulted. The dimensions identified are outlined in Table 1.

In a report prepared by the CRISP Culture and People Task Group (CRISP 2002) on a research strategy for culture and people in construction, a number of dimensions were proposed by construction industry experts. A comparison of these dimensions and the dimensions shown in Table 1 clearly shows that the chosen dimensions are consistent with the aspects considered important in CRISP (2002). This provides validation for the dimensions shown in Table 1 and demonstrates that they are relevant within a CPO context.

Table 1: Dimensions associated with the Egan (1998) agenda for change

Industry problems	Related dimensions
Leadership	Leadership, Control, Professionalism, Participation (decision-making), Communication, Exercising authority
Client focus	Communication, Client education, Respect for client, Sensitivity to client/customer's needs, Monitoring client satisfaction
Team integration	Communication, finger-pointing, Participation, Collaborative working, Openness, Conflict, Subcontracting, Partnering
Delivering quality	Learning & innovation, Emphasis on quality, Performance measurement & continuous improvement, Driving the schedule, Doing it right
Commitment to people	Health & safety, Site tidiness, Respect & Support for workforce, Training, Retention, Commitment to people, Recognizing performance

PROJECT PERFORMANCE

Performance can be considered as an evaluation of how well individuals, groups of individuals or organizations have done in pursuit of specific objectives which generally revolve around satisfying key stakeholders (Mullins 2005). Measures of performance vary significantly, and in construction typically include construction cost, construction time, cost and time predictability, client satisfaction with product and service, defects, profitability, productivity and safety (DTI 2005). In this research, the satisfaction level of participants with project outcomes was used as a proxy of performance. Satisfaction is defined in Chan *et al.* (2002) as the level of 'happiness' of people affected by the project including key project participants. It is an attribute of success, which is both dependent on performance and personal standards or expectations (Liu and Walker 1998). Satisfaction, described *ibid* as an aptitude (an effect or emotion), is thus a subjective assessment of performance.

METHODOLOGY

A quantitative approach was adopted for this study involving a survey research design to obtain a numeric description of trends, attitudes, or opinions of CPOs (Babbie 1990). This kind of research enables researchers to establish "which variables are significant, and to what extent, in a scientific way" (Walker 1997). Data collection was by means of a questionnaire survey of contractors with the unit of analysis being the construction project. The questionnaire was therefore designed to elicit information about the construction project in respect of project characteristics, performance outcomes and cultural orientations. Table 2 shows a sample of the questionnaire items.

Table 2: Sample of questionnaire items

Variable	Measurement
Participant satisfaction	How satisfied was the client with service on Likert scale of 1–5 (very dissatisfied – very satisfied) How satisfied was your company with the level of profitability of this project on Likert scale of 1–5 (very dissatisfied – very satisfied)
Contact & communication with client (C1)	How important was it to the project organization to have lots of contact and communication with the client on Likert scale of 1–5 (no important – utmost importance) During this project there was very little contact or communication with the client on Likert scale of 1–5 (strongly disagree – strongly agree) The project arrangements were such that there was limited access to the client to discuss project-related issues on Likert scale of 1–5 (strongly disagree – strongly agree)

Analysis involved the use of principal component factor analysis to derive a parsimonious set of underlying dimensions that could then be correlated with performance, with multiple regression employed to derive a regression model showing the effects of the cultural dimensions on the performance outcomes. This approach has been utilized in research on culture like Hofstede's (2001) seminal work on culture.

The sampling frame used in the survey was drawn from a database of contractors listed in the UK Kompass (2006) register. Including the pilot survey, a total of 551 questionnaires were mailed out to participants for completion: 85 questionnaires were returned representing an overall response rate of 15.42%; 64 of these questionnaires were analysed in this report.

RESULTS AND DISCUSSION

The profile of projects captured in this survey is presented in Table 3. Most of the projects captured in this survey were private sector new work in the building category, specifically housing and commercial building projects. This outcome is not surprising for a nationwide survey of this nature considering the fact that, according to the DTI, the private sector accounts for some 67% of all construction output, new work accounts for about 53%, building projects make up about 77%, and housing currently constitutes about 40% of construction output in the UK (DTI 2005). Most of these projects were considered by respondents to be either moderately complex or simple.

Table 3: Characteristics of construction projects surveyed

Project type		Number of projects	Percentage of projects
Proj_type1	Public	24	43
	Private	32	57
Proj_type2	New work	34	61
	Refurbishment	16	28
	Redevelopment	5	9
	Demolition	1	2
Proj_type3	Civil Engineering	10	19
	Building	44	81
Proj_type4	Commercial	13	25
	Industrial	7	13
	Housing	13	25
	Infrastructure	6	11
	Leisure	3	6
	Education	3	6
	Mixed use	6	11
	Health	2	4

In terms of the locations of these projects, all the UK regions were well represented, and majority of these projects (41%) had been procured by traditional procurement arrangements. This finding is consistent with RICS (2006). Contract prices ranged from £15K to £18M with contract durations from three weeks to five years. This is a reflection of the range of projects undertaken in the construction industry, from simple jobbing projects to very complex mega projects. Median contract price and duration of the projects were between £0.86M and £2.00M and 9–12 months respectively, consistent with RICS (2006) and DTI (2005).

The main contractor was reported as the most influential project participant overall, and the performance ethos was found to be in the order: health and safety (H&S)–quality–cost–time with H&S as most important and time as least important objective.

It can be concluded from these results that generally, the sample is representative of construction projects in the UK.

The culture of CPOs

Respondents were asked to indicate the extent to which certain perceptions and attitudes, behaviours and conditions existed on the construction project. Orientations were assessed on a scale of 1 to 5, with 1 representing a low orientation and 5 representing a high orientation. Means and standard deviations for each dimension are summarized in Table 4. The lowest rated dimension was *blame culture* (T8), which was rated low. The fact that it was not rated very low implies that a certain level of finger-pointing does exist, meaning that there is some scope for improvement.

The orientations of CPOs on the dimensions of *control of workers' behaviour* (L3), *participation of all participants in planning & goal-setting* (L4), *keeping operatives informed* (L5), *identification with project* (T6), *innovation* (P1), *learning on project* (P2), *monitoring performance* (P3), *waste elimination* (P5), *driving down cost* (P7), *subcontracting* (W1) and *recognizing good performance* (W8) were all neutral. It would have been expected that with all the reports and research commissioned to address the poor performance of the construction industry (cf. Egan 1998), the orientation in respect of dimensions like *monitoring performance, waste elimination* and *driving down costs* would have been very high with CPOs conscientiously striving to achieve better performance. However, this is not the case, according to the data. The remaining dimensions were all rated high. Significantly, no dimension of culture scored very high.

These findings are particularly useful for those seeking change in the culture of the construction industry as it clearly identifies those areas where improvements are possible. Whether such improvements will improve performance requires further investigation.

Principal component factor analysis was applied to these 37 cultural variables not only to demonstrate convergent validity, but also to develop a parsimonious set of dimensions suitable for the subsequent analyses. It has been specified in Hair *et al.* (1998) that the preferable sample size for factor analysis is 100 or larger. However, it has also been argued in Field (2000) that under certain circumstances the sample size may not be critical. For instance, where all communalities are greater than 0.6, samples less than 100 may be perfectly adequate (*ibid*). Indeed, there is even evidence of published research where factor analysis has been performed on similar or much less data (cf. Kaming *et al*. 1997; Liu 1999; Leung *et al.* 2004). Therefore, whilst the potential biases associated with a small size as highlighted in Lingard and Rowlinson

(2006) are noted and whilst recognizing also that the debate on sample size is on-going (cf. Hair *et al.* 1998; Field 2000; Osborne and Costello 2004), factor analysis was considered suitable for the data reduction purposes.

To further test the suitability of the data for the factor analysis, two measures – the Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) and the Bartlett test of sphericity – were obtained. These two tests provide the minimum standard that should be passed. The MSA obtained was 0.776, with .50 specified as a minimum (Hair *et al.* 1998). With the Bartlett test, a significant result was obtained ($p < 0.001$).

To achieve the most representative and parsimonious set of factors possible, a five-component solution was extracted based on the percentage of variance criterion (Hair *et al.* 1998), which specifies that for social science research selecting a solution that accounts for 60% of the total variance is satisfactory. In this research, this coincides with five components that account for 63.863% of the total variance. The varimax rotated components are shown in Table 4.

Table 4: Rotated component matrix showing descriptive statistics of dimensions of culture

			Std.	**Component**				
		Mean	**Dev.**	**1**	**2**	**3**	**4**	**5**
W4	Motivating workforce	3.51	.624	0.816				
T3	Emphasis on teamwork	3.58	.676	0.803				
T7	Free & open communication	3.77	.706	0.757				
W7	Site tidiness	3.86	.702	0.755	0.410			
W8	Recognizing good performance	3.31	.803	0.744				
L5	Keeping operatives informed	3.38	.692	0.733				
L4	Participation	3.19	.720	0.728				
L6	Communication	3.62	.722	0.715				
T4	Dealing with conflict by compromise	3.54	.670	0.695				
T1	Collaborative working	3.94	.615	0.685				
W5	Training	3.58	.834	0.677	0.534			
L2	Supportiveness & appreciation	3.68	.622	0.658				
W3	Respect for all workers	4.07	.678	0.653				
P9	Environmental friendliness	3.58	.698	0.627				
C2	Research into end-user needs	3.65	.851	0.618			0.424	
P2	Learning on project	3.39	.572	0.607	0.406			
L3	Control of workers' behaviour	3.48	.727	0.586				
W2	Showing concern for workers	4.22	.620	0.581	0.413			
C6	Respect for client	4.36	.661	0.528		0.422	0.458	
W6	Safeguarding health & safety	4.22	.677		0.773			
P4	Providing performance feedback	3.51	.638		0.651			
P6	On-time delivery	3.93	.565		0.611			
P8	Quality & getting it right first time	3.94	.604		0.535			
P3	Monitoring performance	3.46	.567		0.480			
T8	Blame culture	2.05	.720			-0.831		
L1	Access and approachability	4.34	.623			0.730		
T5	Information sharing	3.92	.636			0.581		
T2	Trust	3.64	.650			0.532		
P1	Innovation	2.88	.653	0.439		-0.465		
P7	Driving down cost	3.48	.587					
C3	Educating client	3.55	.774	0.410			0.749	
C4	Monitoring satisfaction	3.87	.707				0.683	
C5	Precedence of client's needs	3.78	.700			0.473	0.646	

C1	Contact & communication	4.16	.824				0.553	
T6	Identification with project	3.19	.604					0.716
W1	Subcontracting	3.40	1.068					-0.568
P5	Waste elimination	3.36	.635					0.506

Variables like motivating workforce (W4), emphasis on teamwork (T3), free & open communication (T7), site tidiness (W7), recognizing good performance (W8), keeping operatives informed (L5), participation (L4), and communication (L6) were loaded highly and positively on component one. This component was therefore labelled *workforce orientation*. The highly loaded variables on component two were safeguarding health & safety (W6), providing performance feedback (P4), on-time delivery (P6), and quality & getting it right first time (P8). All these dimensions relate to the delivery of projects to specified standards and was therefore labelled *performance orientation*. Component three had the variables blame culture (T8), access and approachability (L1), information sharing (T5), and trust (T2) highly loaded on it giving an indication of *team orientation*. The variables educating client (C3), monitoring client satisfaction (C4), precedence of client's needs (C5), and contact & communication with client (C1), all clearly making reference to relations with the client, were highly loaded on component four which was therefore labelled *client orientation*. Component five was significant loaded by the variables identification with project (T6), subcontracting (W1) and waste elimination (W5). This component was therefore labelled *project orientation*.

A comparison of these principal dimensions with other research on culture provides some evidence of the validity of these results. For instance people orientation, results orientation, team orientation and client orientation are all discussed in Liu (1999) and Zuo and Zillante (2006).

Participant satisfaction

In this research, participant satisfaction was assessed by aggregating the variables client satisfaction with *service*, *quality*, *cost* and *time*, management satisfaction with *harmony* and *profitability*, operative satisfaction with *site conditions & facilities* and *wages*, and number of *claims*. With the exception of claims, there was a positive association between all the other satisfaction variables indicating that they all vary together. There is support in the construction management literature for this finding, with Dozzi *et al.* (1996) for instance noting that if a project is profitable for the contractor, there is a greater chance of the client being satisfied. The negative association between claims and all the other variables also indicates that claims are inimical to satisfaction. Chronbach's alpha obtained for these nine variables was 0.768. It is not uncommon to find such a measure of participant satisfaction in the research literature (cf. Chan *et al.* 2002; Leung *et al.* 2004; Zuo and Zillante 2006).

A model of culture and participant satisfaction outcomes

The correlation matrix of participant satisfaction and the dimensions of culture (Table 5) shows that satisfaction of participants is significantly and positively associated with the workforce orientation ($r = .299$, $p = .024$) and the team orientation ($r = .351$, $p = .007$). This implies that as workforce and team orientations on a project improve, the satisfaction of project participants also grows. These same relationships were found in Zuo and Zillante (2006), which reported significant correlations between integration, cooperation and people orientation and project team satisfaction.

Table 5: Correlation matrix of cultural dimensions and participant satisfaction

		Workforce orientation	Performance orientation	Team orientation	Client orientation	Project orientation
Satisfaction of participants	Pearson Correlation	.299*	.174	.351**	.148	.073
	Sig. (2-tailed)	.024	.196	.007	.271	.592
	N	57	57	57	57	57

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

In order to assess the predictive ability (or magnitude of effect) of the individual variables, multiple regression was applied to the data (Field 2000). The two variables (team and workforce orientation) were included in the regression by forced entry. Results are presented in Table 6.

From Table 6, the final regression equation for participant satisfaction can be presented as:

PARTICIPANT SATISFACTION = -.012 + .240 (WORKFORCE ORIENTATION) + .359 (TEAM ORIENTATION)

Table 6: Regression analysis results for participant satisfaction

R	.423	Std. Error	.9227				
R^2	.179	Adjusted R^2	.149				
Durbin-Watson	1.828						
Analysis of variance	df	Sum of Squares	Mean Square	F	Sig.		
Regression	2	10.023	5.012	5.886	.005		
Residual	54	45.977	.851				
Total	56	56.000					
Variables in equation	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
(Constant)	-.012	.123		-.097	.923		
Workforce orientation	.240	.125	.241	1.919	.060	.964	1.037
Team orientation	.359	.148	.305	2.429	.019	.964	1.037

Although the results of the t-test indicate that for prediction purposes, it is not worth having workforce orientation in the equation if team orientation is in it ($t = 1.919$, $p = .060$), the value of R^2 for the model (.179) indicates that the two variables account for approximately 18% of the variation in participant satisfaction. The analysis of variance (ANOVA) which tests whether or not the model is a useful predictor of participant satisfaction, gave a highly significant result ($F = 5.886$, $p = .005$), indicating that this model significantly improves the prediction of participant satisfaction. The VIF values (variance inflation factor) indicate that there is no multi-collinearity within the data (Field 2000). Analysis of the residuals and the Durbin-Watson value of 1.828 (Table 6) indicates that none of the assumptions of regression have been violated.

Discussion

The multiple regression confirms the positive associations between participant satisfaction and the workforce and team orientation that was found in the correlation matrix. This finding also reinforces previous research findings in this domain (cf. Zuo and Zillante 2006). As indicated previously, workforce orientation encompasses the amount of effort put into motivating the workforce, emphasis on teamwork, the extent of free and open communication on site, the emphasis on site tidiness, recognition of good performance, keeping operatives informed of project developments, the extent of participation in planning and decision-making by the workforce, communication between managers and operatives, and so on. These aspects have been linked to greater goal commitment, and as found in Leung *et al.* (2004), the greater the goal commitment, the greater the satisfaction of participants. The importance of workforce orientation is also corroborated by evidence in Liu (1999) and Zuo and Zillante (2006). Workforce orientation, generally speaking, is not an area for which the UK construction industry is renowned for exemplifying good practice (Fellows *et al.* 2002). As shown in Table 3, CPOs are generally moderate in orientation in respect of aspects like recognizing good performance, keeping operatives informed and participation in planning and decision-making, and just above moderate in respect of the other dimensions. Improvements in regard of these aspects are therefore called for.

Team orientation encompasses aspects like blame culture (or absence of it), the extent to which management is accessible and approachable, amount of information sharing, and the degree of trust. Because of the fragmented nature of construction, a high team orientation with better integration, cooperation and coordination of construction project teams is often a prerequisite for project success (Cicmil and Marshall 2005). It leads to greater levels of knowledge and cooperation, and as a result more specific goals are set, there is greater goal commitment, and participant satisfaction is improved (Leung *et al.* 2004). This is consistent with Baiden *et al*. (2006), which posit that team orientation promotes a working environment where information is freely exchanged between the different participants. Baiden *et al*. (2006) refer to the "integrated construction project team" in which integration is used to describe the introduction of working practices, methods and behaviours that create a culture of efficient and effective collaboration by individuals and organizations. Team orientation is generally high as can be seen from Table 3, with a low blame culture across the projects surveyed. But there is room for further improvement.

With the evidence presented so far, it appears reasonable to suggest that both workforce orientation and team orientation of construction project organizations can and must be improved, especially as it is universally recognized that these are traits necessary for employee satisfaction and organizational effectiveness (Belout 1998; Robbins 1998; Mullins 2005). Organizational (CPO) effectiveness will in turn translate into management and client satisfaction (Belout 1998).

A CALL FOR DEBATE & FURTHER RESEARCH

A number of questions remain unanswered that call for further debate and research. For instance, whilst it is very easy to recommend on the basis of the empirical evidence uncovered in this research that a lot more effort and resources need to be devoted to improving workforce orientation and particularly team orientation, this also seems to suggest that there is no need for CPOs to pay any further attention to other aspects like performance, client and project orientations because there is no evidence they have an impact. This defies common logic and warrants further examination. Moreover, there are several other measures of performance, some objective like cost, time, H&S and disputes, and others subjective like quality, learning and innovation. Some of these measures of performance may also be associated with the other dimensions of culture. However, this can only be established by further investigation and this could form the focus of subsequent research.

CONCLUSION

This research was undertaken to look for empirical evidence that changes in culture will lead to performance improvement. Here, the satisfaction of participants with project outcomes was measured as a proxy for performance. The results indicate that whilst there are five principal dimensions of culture – *workforce orientation*, *performance orientation*, *team orientation*, *client orientation* and *project orientation* – only team orientation and workforce orientation are directly associated with improved satisfaction. Therefore, it is recommended that CPOs devote more resources towards the improvement of team and workforce orientation for greater participant satisfaction. Although this paper has not explored how such improvements can be achieved, there are a number of texts such as Baiden *et al*. (2006) that are relevant and insightful in this regard and recommended for further reading.

REFERENCES

Allaire, Y and Firsirotu, M E (1984) Theories of Organizational Culture. *Organization Studies*, **5**(3), 193–226.

Ankrah, N A and Proverbs, D (2004) Treading the softer areas of construction management: A critical review of culture. *In:* F Khosrowshahi, (Ed.) *20th Annual ARCOM Conference*, Edinburgh, 551–8.

Ankrah, N A, Proverbs, D, Antwi, A and Debrah, Y (2005) Towards a new approach for measuring the organisational culture of construction project organisations: Overcoming the methodological challenges, *In*: C Egbu and M Tong (Eds.) *Proceedings of PRoBE 2005*, Glasgow.

Babbie, E R (1990) *Survey research methods.* Belmont, CA: Wadsworth Pub. Co.

Baiden, B K, Price, A D F and Dainty, A R J (2006) The extent of team integration within construction projects. *International Journal of Project Management*, **24**(1), 13.

Belout, A (1998) Effects of human resource management on project effectiveness and success: Toward a new conceptual framework. *International Journal of Project Management*, **16**(1), 21–6.

Chan, A P C, Scott, D and Lam, E W M (2002) Framework of Success Criteria for Design/Build Projects. *Journal of Management in Engineering*, **18**(3), 120.

Cicmil, S and Marshall, D (2005) Insights into collaboration at the project level: complexity, social interaction and procurement mechanisms. *Building Research & Information*, **33**(6), 523.

Cooper, M D (2000) Towards a model of safety culture. *Safety Science*, **36**, 111–36.

CRISP Culture and People Task Group (2002) Culture and people in construction – a research strategy, *CRISP Report*, UK.

Dainty, A R J, Bagilhole, B M and Neale, R H (2002) Coping with construction culture: A longitudinal case study of a woman's experiences of working on a British construction site *In:* R Fellows and D E Seymour (Eds.) *Perspectives on culture in construction, CIB report*, **275**.

Dozzi, P, Hartman, F, Tidsbury, N and Ashrafi, R (1996) More-Stable Owner-Contractor Relationships. *Journal of Construction Engineering and Management*, **122**(1), 30–5.

DTI (2005) *Construction Statistics Annuals 2005*. London: Department of Trade and Industry (HMSO).

Egan, J (1998) *Rethinking construction*. London: HMSO.

Fellows, R, Langford, D, Newcombe, R and Urry, S (2002) *Construction management in practice*. Oxford: Blackwell Science.

Fellows, R & Liu, A (2002) Impact of behavioural compatibility on project procurement. *In:* R F Fellows and D E Seymour (Eds.) *Perspectives on culture in construction.* CIB.

Fenn, P, Lowe, D and Speck, C (1997) Conflict and dispute in construction. *Construction Management and Economics*, **15**(6), 513–18.

Field, A P (2000) *Discovering statistics using SPSS for Windows: advanced techniques for the beginner*. London; Thousand Oaks: Sage Publications.

Hair, J F, Anderson, R E, Tatham, R L and Black, W C (1998) *Multivariate data analysis*. Upper Saddle River, NJ: Prentice Hall.

Hofstede, G (2001) *Culture's consequences: comparing values, behaviors, institutions, and organizations across nations.* London; Thousand Oaks, CA: Sage Publications.

Kaming, P F, Olomolaiye, P O, Holt, G D and Harris, F C (1997) Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management and Economics*, **15**(1), 83–94.

Keesing, R M (1974) Theories of culture. *Annual Review of Anthropology*.

Kompass (2006) *Kompass: the authority on British industry. [Vol.1]. Products and services*. East Grinstead: Reed Information Services.

Leung, M-Y, Ng, S T and Cheung, S-O (2004) Measuring construction project participant satisfaction. *Construction Management & Economics*, **22**(3), 319.

Lingard, H and Rowlinson, S (2006) Letter to the Editor. *Construction Management & Economics*. London: Routledge.

Liu A M M (1999) Culture in the Hong Kong real-estate profession: a trait approach. *Habitat International*, **23**(3), 413–25.

Liu, AMM and Walker, A (1998) Evaluation of project outcomes. *Construction Management & Economics*, **16**(2), 209.

Mullins, L J (2005) *Management and organisational behaviour*, 7ed. Harlow: Prentice Hall/Financial Times.

Newcombe, R (2003) From client to project stakeholders: a stakeholder mapping approach. *Construction Management and Economics*, **21**, 841–8.

Ngowi, A B (2000) Impact of culture on the application of TQM in the construction industry in Botswana. *International Journal of Quality & Reliability Management*, **17**(45), 442–52(11).

Ofori, G (2000) Challenges of construction industries in developing countries: Lessons from various countries. *In*: *2nd International Conference on Construction in Developing Countries: Challenges facing the construction industry in developing countries.* Gabarone, Botswana. Available online: http://buildnet.csir.co.za/cdcproc/2nd_proceedings.html

Osborne, J W and Costello, A B (2004) Sample size and subject to item ratio in principal components analysis. *Practical Assessment, Research & Evaluation*, **9** (11).

Phua, F T T and Rowlinson, S (2003) Cultural differences as an explanatory variable for adversarial attitudes in the construction industry: the case of Hong Kong. *Construction Management and Economics*, **21**, 777–85.

RICS (2006) *Contracts in use: A survey of building contracts in use during 2004*. London: The Royal Institution of Chartered Surveyors.

Riley, M J and Clare-Brown, D (2001) Comparison of cultures in construction and manufacturing industries. *Journal of Management in Engineering*, **17**(3), 149–58.

Robbins, S P (1998) *Organizational behavior: concepts, controversies, applications*. Upper Saddle River, NJ: Prentice Hall.

Rooke, J (2001) Developing a culture of quality in the British construction industry: a report on research in progress. *In:* W Tijhuis (Ed.) *Culture in construction* **-** *Part of the deal? CIB Proceedings*, Twente, The Netherlands, **255**.

Schein, E (1985) *Organizational Culture and leadership*. San Francisco: Jossey-Bass Publishers.

Serpell, A F and Rodriguez, D. (2002) Studying construction organisational culture: Preliminary findings. *CIB Report*, **275**, 76–91.

Simon (1944) *The placing and management of building contracts: report of the central council for works and building.* London, HMSO.

Smircich, L (1983) Concepts of culture and organisational analysis. *Administrative Science Quarterly*, **28,** 339–58.

Soetanto, R, Proverbs, D and Cooper, P (1999) A conceptual model of performance and satisfaction for main participants of construction project coalitions. *In: Proceedings of ARCOM 15th Annual Conference*, John Moores University, Liverpool, ARCOM.

Thomas, R, Marosszeky, M, Karim, K, Davis, S and McGeorge, D (2002) The importance of project culture in achieving quality outcomes in construction. *In: Proceedings IGLC-10*, Gramado, Brazil.

Walker, D H T (1997) Choosing an appropriate research methodology. *Construction Management & Economics*, **15**(2), 149.

Zuo, J and Zillante, G (2006) Project culture within construction projects – A pilot case study. *The International Journal of Construction Management*, **6**(2), 15–29.

USER ANALYSIS AND END-USER INVOLVEMENT

Ritsuko Ozaki[1] and Satoshi Yoshida[2]

[1] *Imperial College London, Tanaka Business School, London SW7 2AZ, UK*
[2] *University of Tokyo, Institute of Industrial Science, 4-6-1 Komaba, Meguro, Tokyo 153-8505, Japan*

The customer focus literature claims that end-user orientation can help firms boost their businesses, including the construction industry. However, satisfying customers is not easy, as customers are complex and have different requirements. This is particularly true in the building industry, which accommodates numerous different users. In this light, by using architectural concepts of ‘user composition’, ‘product functions’ and ‘product structure’, this paper presents a way of categorizing end-users to clarify their product function requirements. This categorization can facilitate a firm in developing a more focused product that meets the diverse requirements of its customers. The paper also discusses the ways end-customers can be involved in construction projects and design processes. Such involvement can give end-users a sense of ownership and thus make them satisfied customers.

Keywords: architecture, client, construction management, design and build.

INTRODUCTION

Why does the industry need to analyse and understand its users? In recent years, many researchers in marketing have stressed the importance of the need for satisfying users. They believe that high customer satisfaction leads to successful business. This is due to customer loyalty (i.e. their willingness to return to the same provider) and/or to the positive reputation gained by the firm through a satisfied clientele base (i.e. word-of-mouth referrals). For example, Japanese housebuilders generate extensive business from customer loyalty and word-of-mouth sales (Barlow and Ozaki 2005). In order to achieve high levels of customer satisfaction, it is crucial for any businesses to capture what users require and produce products that meet those requirements.

In this light, based on a literature review, this paper presents a conceptual discussion as to how users can be classified and analysed, and how their requirements can be incorporated into product development (i.e. building projects). This will be done through the use of architectural concepts, which demonstrate the importance of understanding complex customer specificities in the competitive marketplace.

This paper initially discusses the concepts of ‘co-production’ and ‘user innovation’, which emphasize the importance and significance of user involvement in product development. After reviewing this literature, the paper introduces the architectural concepts of ‘user composition’, ‘product function’ and ‘product structure’. These concepts are then used to describe the characteristics of design processes and the complexity of users. In turn, this helps us to categorize users and their required product function and facilitates a more focused product customization. Finally, the paper presents a case study of a construction project in which the ways of involving

[1] r.ozaki@imperial.ac.uk

end-users in the product development process are examined and lessons are drawn from it.

CO-PRODUCTION AND USER INNOVATION

There are difficulties in meeting user demands especially when there are so many users with diversified and sometimes conflicting requirements. Therefore, one important question in construction projects is how to reflect user requirements in the actual physical form of buildings. In order to produce a building on users' terms, the product must have a certain degree of flexibility to meet individual aptitudes and interests. For example, this can be achieved by increasing customer choices in design and increasing user involvement in the decision-making process. In the housebuilding business in Europe, customers' design participation has become widespread. As an instance, flexible plan forms (i.e. the possibility of changing the internal layout of developments after they have been built) in France and the communal covered open space in Denmark result from user design participation (Woolley 1994). Such participatory housing may look fairly conventional, but on closer inspection, one can see the influence of users in many different ways, such as internal layouts, as well as choices of house types available to users. These examples suggest that user participation can bring about innovation in house building. Innovative approaches such as this can lead to new and more user-friendly forms of housing design, reflecting users' interests and ideas (ibid.).

A company can offer each individual user the chance of contributing to product design by bringing the user into the product development process. This will be a method for the business to adapt to the requirements of the users and tailor the product specifically for them (McKenna 1991). The literature of 'user innovation' claims that users feel satisfied with innovative companies and innovative products and services which materialize their requirements and desires (Ellis and Curtis 1995). Moreover, an accurate understanding of user needs is identified as a key to success (Herstatt and von Hippel 1992). Feedback from them, as well as an accurate understanding of their contexts, is crucial to desired outcomes (Herstatt and von Hippel 1992; Leonard-Barton 1984).

Indeed, users' participation in design has become widespread. Some companies put emphasis on pro-active user relationships by anticipating what users like and learning from them in order to provide customer-focused products and services. In particular, when a product has many unspecified users with highly heterogeneous requirements, a product that reflects the average user requirements will leave many of the users dissatisfied. One way of responding to this problem is to enable users to modify products to create a better fit to their own requirements. This approach has become common in the development of software applications (Franke and von Hippel 2003; Lakhani and von Hippel 2003). Skilled users can create customized and superior versions by integrating their knowledge into product design (Leonard-Barton 1984; von Hippel 1988), and the experiences of those 'lead users' do present solutions to problems (Slaughter 1993). This leads to a high level of customer satisfaction. Lead users need the product and also the ability to make improvements on that particular product in order to use it. As lead users, they like working on the problem and improving the product and they enjoy the reputation gained from making high-quality contributions to its development (von Hippel 2005).

Similarly, the literature on ‘co-production’ emphasizes users’ active involvement in product development. Udwadia and Kumar (1991), for example, talk of ‘co-construction’ of new products, which takes into account user requirements through information technology. This process can include user experimentation and subsequent design modifications, and leads to a close collaborative relationship between producers and consumers/users, and subsequently a shared ownership of the final product. In such co-production, users can play an active role in the production of goods and services on their own terms (Ostrom 1996). Positive attitudes towards bringing users’ ideas into the product development process of design, delivery and after-care can change the whole situation. Innovative approaches such as this can lead to new and more user-friendly forms of products and services which reflect user requirements.

However, construction is different from software. End-users cannot modify the product on their own and create an improved or customized version like they might do with software. So, the question is: How can users’ heterogeneous needs and requirements be incorporated into product design? Architects and designers need to obtain feedback on in-use performance of the products. Thus, what they need is a voice from people who actually use the product, even though their experience and knowledge cannot be integrated in the same manner as computer software design. In this light, the following sections discuss ways of co-producing buildings.

USER ANALYSIS

There are certain features of the construction industry that potentially make it difficult to identify who their customers are. Unlike in some sectors where end-users are clearly ‘seen’ (e.g. banking) and therefore their requirements are easily taken into account, in the construction industry end-users tend not to be regarded as customers by firms who customarily are inclined to think only of their immediate clients. For example, in the social housing sector, the customers of a construction company are usually local authorities, and end-users who will actually live in the houses are often not taken into consideration in the product development process. Goldman et al. (1995) found that fewer than 10% of industrial and service firms consider the end-users to be their customers.

Nonetheless, the requirements of ‘ultimate customers’ cannot be neglected. Feedback and information from end-users must be incorporated into the product development and design process. Specific requirements of end-users have to be captured in order to achieve a maximum level of customer satisfaction, which ultimately will contribute to the success of the business. Therefore, we need to know who the end-users are, what their requirements are and how they can be involved in the product development and design process. To answer these, we use a few architectural concepts, such as ‘user composition’, ‘product function’ and ‘product structure’.

Characteristics of design process mechanism

In order to discuss how users can be involved in product development, and how their requirements can be incorporated into design, we will first show the mechanisms of the design process and its characteristics (Figure 1). The diagram below shows that the four phases in the architectural design process influence each other with feedback constantly being given. It is also clear that customers and their requirements form the basis of the design process.

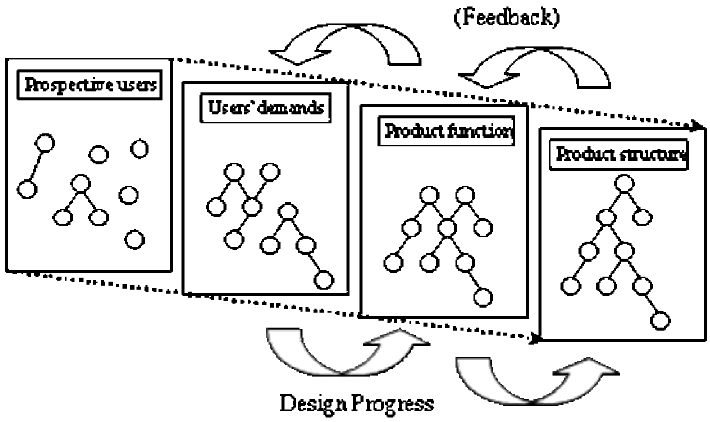


Figure 1: Four aspects of the design process

Prospective users
There are different types of prospective users for each product. The prospective users have different characteristics and may have structural relationships among themselves (user structure). For example, while some products are used only by individual customers, other products are meant for a large number of the general public.

User demands
The totality of user requirements is closely linked to user structure. It is quite straightforward to understand the requirements of single users, but it becomes complex when a product has many different users. The level of difficulty becomes greater particularly when the users of a product cannot be identified. User requirements can vary greatly but remain unidentified. Furthermore, the requirements of users can be things such as wishes, hopes and feelings, which cannot be clearly expressed and, therefore, sometimes come into conflict with each other.

Product function
A product is developed based on the composition of various product functions (Fujimoto 2002). It is therefore essential to make product functions right in order to make the product right. However, different users possibly require different functions from the same product. This heterogeneity nature of users and their requirements suggests the importance of understanding the relationship between user characteristics and product functions, which we will look at in the next section.

Product structure
The product structure is constructed based on product functions (Ulrich *et al*. 1995). At this stage, the developer or producer of a product could have strong input into the product design based on their experience and knowledge. This could result in an end product showing the design/architectural firm's usual design characteristics (Fujimoto *et al*. 2001), which may not necessary reflect users' ideas.

It is clear that we need a good understanding of users and their characteristics in order to produce a product whose functions meet their demands.

Classification of user composition
Product users differ in each industrial sector. For example, in the case of personal computers, the users are independent from each other, whereas public buildings are built for the use of a large number of the general public. These two cases have distinct types of user groups, whose requirements affect the process of product development.

Figure 2 shows a comparative analysis of user characteristics in a number of industrial sectors. Elements on the left column are products from different sectors, and the rows show functional characteristics and the number of potential users.

		Multiple functions			**Single function**		
		A large number of the general public	A large number of private groups	A single user	A large number of the general public	A large number of private groups	A single user
Single production	City Hall	Entrance hall, Conf. room, Track bay	Offices, Meeting room	Mayor's office	Lift, Restaurant,	Locker room, Store-room	-
	Residence	-	Living room	Children's room	-	Bath-room	(Kitchen)
Mass production	Private Car	-	-	Driver's seat	-	-	Rear seat
	PC	-	-	o	-	-	-
	Application software for PC	-	-	-	-	-	O
	Dining Table (restaurant)	-	-	-	o	o	O
	Office Desk	-	-	o	-	-	-

Figure 2: User composition

Every product has a specific composition of prospective users. Here, we identify three types of users: a single user, a number of private groups and a number of the general public. The difference between the three user types has significant impacts on product design.

For products with ‘single-user’ and ‘single-function’, such as software applications, the user requirements can be captured straightforwardly. Products of this type have a main function that characterizes them and so customers can select the function that best fits their needs.

In the case of products with ‘single-users’ but with ‘multiple-functions’, it is more complicated to adjust functions to user requirements. Mobile phones and personal computers are examples of this type. Every customer principally wants not only the main function, but also certain sub-functions to meet their individual requirements. Conflicts between requirements for sub-functions need to be resolved by prioritising sub-functions.

Products of ‘multiple-users’ and ‘single-function’ have two user types: a number of private groups (specific users) and the general public (unspecific users). The simplicity of the single function can be understood with the example of a bathroom: one takes a bath in the bathroom. The requirements of product functions are therefore straightforward, and this example suggests that engineers can focus on a single product function without any conflicts in relation to user requirements.

The most complicated type is ‘multiple-users’ and ‘multiple-functions’, such as the living room of a house, and the entrance hall and conference rooms of a city hall. The former concerns multiple users that are a private group of people (e.g. family), and the latter relates to multiple users of unspecific groups of people (e.g. the general public). In both cases, users often have specific requirements, and engineers and/or architects try to meet the users’ expectations with regard to the main functions and sub-functions of the product. This requires them to hold consultation sessions with their clients. While it is relatively easy to obtain opinions about the living room from all of the family members of a house, it is much harder to obtain all the differing opinions on the entrance hall of a city hall from its potential users. Clearly, the user structure (e.g. specific customers vs. a large number of the unspecific general public) has a significant effect on product functions, and consequently on product structure. Figure 3 shows the complexity of a product with “multiple-functions” and “multiple-users” of the “general public”, and the importance to obtain information in the development of products of this type.

User type	Single function	Multiple functions
single users	application software	cell phone, PC
a large number of a private group of people	private car	residence
a large number of the general public	tram	city hall

Figure 3: Key points of customer composition and product function

An analysis of users, based on the architectural concepts of user composition, can provide a ‘framework’ for a better understanding of the complex relationships between user characteristics, product functions and product structure, and consequently of user requirements. This user classification approach can be applied to a product with complex features, such as a public building, where users can be quite diverse within one product class. By categorizing multiple users according to their use of the building, their wide-range and distinct function requirements can also be categorized. In turn, this helps the producers and architects to work better on the design of each of the product functions. User composition can help firms to segment their customers, which facilitates a more user-oriented production.

INVOLVING USERS IN DESIGN PROCESS

So, how can users, especially end-users, be involved in the design process and express their opinions, and how do they take part in product development?

In recent years, the scale of building projects has increasingly become bigger. These projects have a greater impact on their social and natural environments and, therefore, leave many issues to be resolved (e.g. structure, material, cost, schedule, environmental factors such as wind, temperature and earthquakes, etc.), which small projects do not necessarily have to deal with (Yoshida and Yashiro 2004). Thus, large projects inevitably have more stakeholders. For example, a project to build a city hall has a number of stakeholders including the mayor of the city (i.e. client), architects, construction engineers and other engineers, researchers and citizens (i.e. end-users). Furthermore, such a large project is likely to have many users – both specific and unspecific – and therefore the number of functions required by different users and issues to be solved are significantly more than, and different from, those involved in a project building a residential house that is used only by its household members.

In a large building project, while construction engineers deal with issues and agendas that are physical, architects make sure that the design is made from not only the pure design perspective, but also from the historical, social and psychological viewpoints. This requires the architects to consult with people who are aware of the historical and psycho-social contexts. This is where end-users ‘can’ come into the picture. End-users’ opinions about the project can be collected and discussed in a number of forms. The bigger the project is, the more information is required. Typically in a large building project, formal interviews with representatives of the public and/or a questionnaire surveys involving the wider public are conducted. But consultation exercises can also be held. These have more elements of active user participation than mere interviews and questionnaire surveys. Such public consultations, i.e. meetings that involve both designers and users, include the ones with international environmentalist groups to discuss ecological matters.

There are a few stages in end-user involvement in the design process. We identify three levels: (1) input and feedback, (2) controlling and (3) accomplishment. ‘Input and feedback’ is the least pro-active form, in which end-users put forward their demands and see how their demands are treated. In ‘controlling’, end-users are involved in the actual design process and get to observe how the project is being conducted, but they are not involved in the technical aspects of it. Lastly, end-users get involved in all levels of activities (‘accomplishments’). In this case, they develop abilities to technically intervene in the project. In reality, the first two levels are more feasible and should be achieved in building projects, but end-users’ technical intervention can be difficult to achieve.

There is an advantage to such active end-user participation. Alexander (1964) points out that user participation makes a strong sense of solidarity among participants. Such solidarity helps them explicitly express their requirements, which otherwise may remain unsaid, and thus make them strongly motivated as participants. With the experience of participation in product development, the end-users’ sense of responsibility will be raised; and their newly acquired sense of responsibility concerns not only the project context itself, but also many other issues including the environment and culture.

Through looking at the ways in which users can be involved in (public) building projects, we identify four implications of end-user participation in general:

- The expansion of the boundary of the meaning of “customers”.
- Customers (end-users) taking part in many aspects of a project (design, product development).
- Customers developing their sense of ownership and responsibility through the experience of the participation.
- Participation helping the concepts (social meaning) of the product (e.g. a city hall foyer as ‘a place of comfort’ for the general public) to penetrate into society.

A case of a university building

However, current design practices have not fully embraced this concept of active end-user involvement. The following reported case shows which parts of end-user participation need improving.

In his report, Peterson (2003) gives an account on user perceptions of a new university building, which was a 25 million pound project with the total net (i.e. usable) space of 3,600m^2. He finds in his questionnaire survey and face-to-face interviews that there are criticisms of the open-plan workspace, cellular space and the reduction in storage and shelving space. In a university, there are different users: lecturers, researchers, administrators, students, anonymous visitors and many other support staff. Each of these stakeholders has different ways of using the building space and therefore different requirements. However, the different and diverse ways of use do not appear to be considered well. Peterson summarizes that, although staff approve of the new building project overall, the quality of the office space is perceived by the vast majority of staff to be inferior to the space they were occupying at the time his survey was conducted.

> "Not sure how all colleagues will get on working with each other. We have different ways of working and so this may cause friction" (administrative staff).
>
> "I worry all my stuff won't fit in new offices and I will need a big clear out" (academic staff).
>
> "I think the new building will look better from the outside and is good in terms of image but I have concerns about the lack of space and general working conditions. The work environment will be cramped for support staff and morale could drop. This could affect the standard of work" (administrative staff).
>
> "All the money seems to have been spent on the shop front with savings made on the poor quality office space" (administrative staff).
>
> "The new building may get us back into proximity with each other, at least for more of the time than we have at present, but I'm sure that we will find ways of restricting access to students who may wish to interact with us. The greater emphasis on research outputs will no doubt give staff the excuse not to come into the school" (academic staff). (Source: Peterson 2003: 36, 43, 45)

The design of the new building is in general unpopular and its users are dissatisfied. One of the reasons why so many staff complained about their office space is because the consultation was done only with the former Head of the school who acted as a representative for the whole institution. His vision was to increase communication and foster interactive culture, and the design of the building does reflect it; however, it fails to reflect the way that individual staff in the school work.

Communication seems to be encouraged and facilitated well by the new design, which embraces the interactive culture (e.g. the café forum area where there is a café and space for discussion). In press advertisements, the school says that it is a "truly friendly and helpful" place, a claim reflecting the vision of the school. The new building will bring about more contact between staff and students and will change the old culture:

> "We lost a lot of the out-of-class contact that we may have had with them (the students), and the College Senior Common Room has become the focal point for (students') coffee and lunch breaks…We make much of our so-called friendly atmosphere" (academic staff). (Source: Peterson 2003: 45)

Contrary to dissatisfaction with the physical design of the building, Peterson's respondents seem to approve of the image that the new building creates. His respondents – academic staff, administration staff and students – all agree that the new building is important to enhance the reputation of the school. They think that the new physical environment will change the image of the school and take it forward in a competitive global market:

> "The new building will have a symbolic impact, the investment suggests that the school is going places and has the full backing of the college. It will also help for PR and marketing purposes" (academic staff).
>
> "It will play a symbolic role in defining the new business school and … may signal a break away from the old business school culture" (student).
>
> "It will help the school present a more modern image and attract better calibre staff and students" (student). (Source: Peterson 2003: 38, 43)

Peterson (2003) also interviewed the Rector of the college and the financier of the new building project. In the interview, the Rector says that the new frontage and entrance are 'critically important' in providing the college overall with a modern and outward looking face. The funder also mentions the poor signage and physical presence of the college was a fundamental driving force in his desire to bequeath the money to fund the project. Peterson believes that the building project will become part of the corporate identity of the school and can potentially play an important role in the future success and growth of its brand.

This case illustrates the importance of recognising who the end-users are and of consulting them to understand the way in which they work and how they use their work space. The problem with this particular project was that only the Head of the school, who was also one of the end-users, was consulted by the designers. Although his view on increasing communication and interaction was reflected and shared among the staff and students, his perception of the way other staff worked and used the building and space was not representative of the majority. This suggests that representatives from each of the different stakeholders (e.g. lecturers, researchers, senior administrators, administrative staff and students) should have been invited to user consultations.

So, in light of our four implications of end-user participation (see above), the following lessons can be drawn from this case.

- The expansion of the meaning of customers: to identify end-users in each category of stakeholders is crucial.
- End-users taking part in various aspects of a project: various end-users need to be part of not only the image and vision of the school, but also the physical design, which should reflect the way they work.
- Users developing a sense of ownership and responsibility through participation: without being involved, end-users do not feel that they own the project or building and do not feel responsible for the project or the impact that the building creates.

- Participation helping to penetrate the social meaning of the product: the new culture, images and visions need to be fully shared among all the stakeholders during the consultation, rather than after the implementation.

CONCLUSION

As the concept of co-production suggests, users' active involvement in the product development process can lead to success in business. Users get the product made on their terms; and this gives them a sense of ownership and makes them feel satisfied. Satisfied customers are always good news for a firm. User analysis based on architectural concepts can help any firm to analyse their customers and their function requirements in order to meet user requirements and ultimately to make their projects and therefore their businesses more successful.

However, product users are complex. Firstly, the term encompasses many different types of customers, including end-users who actually use the product and are often overlooked in the product development and design processes. Secondly, there can be different kinds of end-users for one product and this implies they have different function requirements. However, in the light of the customer satisfaction, it is crucial for any firm to identify who the customers are, to analyse what they require and to reflect their requirements in the end product.

This paper has shown how user characteristics and their demands form the foundation of product design by using the architectural concepts. The paper has discussed approaches to involve users in the process of product development and implications of their participation. The case study of building a new university building has offered a number of lessons, which raises our awareness of the complexity of user composition, their requirements, and the way representative end-users can be involved in the design process. Nonetheless, despite the complexity and difficulty, design practitioners should maximize end-user involvement. This paper only offers the concept and does not involve any empirical studies. The next step therefore would be to look at a real building project and analyse the way end-users participate in the project and make recommendations to the actual practice.

REFERENCES

Alexander, C (1964) *Notes on the Synthesis of Form*. Cambridge, MA: Harvard University Press.

Barlow, L and Ozaki, R (2005) Building mass customised housing through innovation in the production system: lessons from Japan. *Environment and Planning A*, **37**, 9–20.

Ellis, L W and Curtis, C C (1995) Measuring customer satisfaction. *Research Technology Management*, **38**(5), 45–8.

Franke, N and von Hippel, E (2003) Satisfying heterogeneous user needs via innovation toolkits: the case of Apache security software. *Research Policy*, **32**(7), 1199–215.

Fujimoto, T, Aoshima, Y and Takeishi, A (2001) *Business Architecture*. Tokyo: Yuhikaku.

Fujimoto, T (2002) Architecture, capability, and competitiveness of firma and industries. Discussion Paper CIRJE-F-182, Centre for International Research on the Japanese Economy, Faculty of Economics, University of Tokyo.

Goldman, S L, Nagel, R N and Preiss, K (1995) *Agile Competitors and Virtual Organisations: Strategies for Enriching the Customer*. New York: Van Nostrand Reinhold.

Herstatt, C and von Hippel, E (1992) From experience. Developing new product concepts via the lead user method: a case study in a “low-tech” field. *Journal of Product Innovation Management*, **9**, 213–21.

Lakhani, K R and von Hippel, E (2003) How open source software works: "free" user-to-user assistance. *Research Policy*, **32**(6), 923–43.

Leonard-Barton, D (1984) Diffusing innovation: when the users are not the choosers. *Knowledge: Creation, Diffusion, Utilization*, **6**(1), 89–111.

McKenna, R (1991) *Relationship Marketing: Successful Strategies for the Age of the Customer*. Reading, MA: Addison-Wesley.

Ostrom, E (1996) Crossing the great divide: coproduction, synergy and development. *World Development*, **24**(6), 1073–87.

Peterson, M (2003) How do Business School students and staff perceive the Tanaka project and what is its meaning to the Business School? MBA Project Report, Imperial College London, London.

Slaughter, S (1993) Innovation and learning during implementation: a comparison of user and manufacturer innovations. *Research Policy*, **22**, 81–95.

Udwadia, F E and Kumar, E R (1991) Impact of consumer co-construction in product/service markets. *Technological Forecasting and Social Change*, **40**(3), 261–72.

Ulrich, K (1995) The role of product architecture in the manufacturing firm. *Research Policy*, **24**, 419–40.

Von Hippel, E (1988) *The Source of Innovation*. Oxford: Oxford University Press.

Von Hippel, E (2005) Democratizing Innovation, Cambridge, MA: MIT Press.

Woolley, T (1994) Innovative Housing in the UK and Europe. *In:* R Gilroy and R Woods (Eds.) *Housing Women*. London: Routledge.

Yoshida, S and Yashiro, T (2004) Study on the concept of “architecture” to describe construction products. *In: 10th Annual Conference CIB W104 Open Building Implementation*, Paris, 21 September.

PROPERTY ASSET MANAGEMENT IN THE UK CENTRAL CIVIL GOVERNMENT

Steven Male[1], Dragana Mitrovic[2], Marcus Gronqvist[3], Drummond Graham[4] and Martin Graham[5]

[1,2]*School of Civil Engineering, University of Leeds, Leeds, LS2 9JT, UK*
[3]*Value Solutions Ltd, Ilkley, West Yorkshire, LS29 9NE, UK*
[4] *Thomson Bethune, Edinburgh, EH3 6BJ, UK*
[5]*Initiate Consulting, London, SE1 2NE, UK*

An overview of a policy focused research study to improve property asset management across the UK civil government estate is presented. The study was commissioned by the UK's Office of Government Commerce (OGC). Property asset management involves the whole life management of property assets from 'cradle to grave' and is defined in the study as covering land and built assets, including buildings and civil infrastructure used by a central government organization, regardless of tenure. An interlocking research methodology was adopted for the study combining literature research, questionnaires, interviews and a policy workshop. The study was conducted to inform the development of the OGC's embedding programme for property asset management. The three principal research results are presented; a property asset management board to overcome fragmentation of the central civil government estate, a maturity matrix in property asset management and a route map to excellence.

Keywords: asset management, benchmarking, central government, government departments, property management.

INTRODUCTION

The paper presents the context and results of policy-oriented research conducted between December 2005 and May 2006 and commissioned by the UK's Office of Government Commerce (OGC), an independent office of Her Majesty's Treasury (HMT). The research (OGC University of Leeds 2006) investigated the improvement of property asset management (PAM) within the £220bn central civil government estate (CCGE). The report was launched at an OGC Conference in June 2006 by the Chief Secretary to the Treasury, the Right Honourable Stephen Timms MP, and following a period of consultation he launched subsequently the route map to excellence in November 2006 (OGC 2006).

The OGC study sits within broader international developments dealing with the management of physical assets at national, regional and local government levels. The Australian Federal and State governments have addressed this issue for a number of years (ANAO 1995; ANAO 1998; ANAO 2003; DPWS 2001; APCC 2001; Barrett 2003; NSWT 2004; DTF 2005). The Federal Government of the United States identified real estate and its management as a high risk Federal programme in January 2003 due to significant underinvestment (FRPC 2004). In that same year the General Accounting Office testified that Federal property is deteriorating seriously and that there is insufficient reliable data on which decision makers can base future investments in physical assets. In the UK local authorities have analysed and justified their

[1] stevenmale@stevebbcm.u-net.com

investment in physical assets for some time (Audit Commission 2000). The OGC has conducted previous research into workplace strategies within the CCGE (OGC University of Reading 2004). The research reported here also has a direct relationship with three parallel studies in the CCGE. The first is to determine the skills framework necessary for property asset management as part of the wider Professional Skills for Government initiative (OGC Howarth 2006). The second involved benchmarking and measuring property management in the CCGE (IPD 2005; OGC 2006) and the third, conducted by the UK National Audit Office (NAO 2006), investigated the better use of public sector assets.

The research study was also conducted against the background of the UK government's Efficiency Programme (Gershon 2004), the relocation of civil servants outside London and the South East (Lyons 2004a), the Comprehensive Spending Review 2007, and a fundamental review of government expenditure on and the better management of public sector assets (Lyons 2004b). The second Lyons' report had a direct consequence for the OGC study reported here, setting a series of targets to be achieved by 2010, including identifying potential savings in the order of £760m that could be made from within the management of the administrative central civil government estate (CCGE); that is, the estate used to support the managerial and administrative 'machinery' of government. This target set the initial reference point and strategic context for subsequent efficiency gains as part of the research.

STUDY SCOPE, DEFINITIONS AND METHOD

The study was commissioned to inform the development of OGC's embedding programme for property asset management within the CCGE. The study scope was to address:

- base-lining the current state of property asset management in central government as a datum against which the success of OGC's embedding programme can be assessed;
- developing a series of models or frameworks to promote property asset management excellence in the CCGE and also setting out a model of maturity for PAM against which central government departments and other central public sector organizations are able to judge their own status and progress towards excellence;
- clarifying the effectiveness of options for central interventions that could result in potential efficiency gains which would also guide the development of OGC's embedding programme.

The study defined property asset management (PAM) as a holistic approach for aligning service delivery requirements with the performance of property assets over time to meet business objectives and drivers for a central government organization. Property assets comprise land and built assets including buildings and civil infrastructure. PAM has a strategic component dealing with investment in property over the long term – three, five and up to 10 years and beyond; and an operational component covering the short to medium term – one to three years – within which budgetary allocations operate. The issues related to time dimensions will be addressed further in the discussion and conclusion section of the paper. The study differentiated between property assets that are *operational*, involving a close relationship between physical assets and frontline service delivery and *administrative* assets supporting the 'machinery' of government, comprising primarily commercial office accommodation and also the primary focus of the study.

Research methodology

From the outset the PAM study had a policy driven focus. A triangulated research methodology was adopted (Blackie 2000). Existing best practice was identified through literature research, supported by empirical fieldwork conducted previously for a significant government agency to develop a national asset management framework to manage the agency's £23bn asset base and £300–400m annual capital and operational expenditure programmes; this methodology influenced the method for the OGC study. The researchers also shared information with other ongoing OGC and NAO projects as noted above.

The literature review covered national and international Government sources noted earlier and also reports produced within the UK private sector (RICS 2002) and from professional institutes (IAM 2002; RICS 2005). An OGC questionnaire was piloted and distributed to the heads of estate of 86 government departments. Multiple follow-ups were instigated by OGC personnel; 49 questionnaires were returned, a response rate of 57%. Response rates of 20–30% can be anticipated using no follow-ups and 50–70% using multiple follow-up procedures; the response rate for this study can be considered good. Data were analysed both quantitatively with simple frequency distributions and qualitatively from comments made through the use of open-ended questions.

Interviews were held with 32 individuals across a range of government organizations, 30 with heads of estate (horizontal data collection) and two detailed interviews with more senior personnel within two major departments (vertical data collection). Interviews were conducted across different sizes of government departments, from those with responsibility for managing significant government property assets nationally and regionally to smaller departments occupying perhaps only three floors or less in a commercial office block. Additionally, detailed examples of estate management strategies were also provided by a number of central government departments and organizations. A 2.5-day policy workshop was conducted comprising the Leeds research team, OGC and invited delegates from government departments, executive agencies and non-departmental public bodies (NDPBs) (or arms-length bodies – ALBs – as they are sometimes termed).

Property assets and the public sector

Sir Michael Lyons (Lyons 2004b) noted that as at December 2003 the whole of the public sector owned assets worth around £658 billion; £220 billion or 33% is held by central government and ALBs. An important issue for the research was the definition of property assets within the UK central civil government estate. In August 2005 the Cabinet Office set out a classification of new and existing bodies falling within departments' remit to ensure appropriate structures and governance arrangements are in place (Cabinet Office 2005a).The remit of the study covered directorates within departments; departments running on agency lines; executive agencies; public–private partnerships; offices 'independent' of their parent departments (such as the Office of Government Commerce and the Office of the e-Envoy); executive non-departmental public bodies (NDPBs); government-owned companies; and contracted-out services.

As at March 2005 there were 910 public bodies sponsored by UK government departments (Cabinet Office 2005b) made up of 21 public corporations, the Bank of England, 26 NHS bodies and 861 NDPBs. The NDPB group comprises 211 executive NDPBs, 458 advisory NDPBs, 42 tribunal NDPBs and 151 independent monitoring boards, the arms-length bodies (ALBs) referred to earlier. The impact on the management of the CCGE is considerable; much of the asset base resides out of the immediate direct control of central departments, and is under the control of either executive agencies or other ALBs. As of the third quarter of 2005, there were 533 690 members of central civil service staff in post (ONS 2005), approximately three-quarters of these work in executive agencies (ALBs), and approximately 130 000 working directly within central government departments. Thus, a significant proportion of the associated space to accommodate civil servants also resides within these types of structures. The full impact of potential efficiency gains across the CCGE using a more integrated approach to property asset management has to be secured within a highly decentralized and fragmented government structure – an important challenge for the research study and addressed through research outcomes.

RESEARCH RESULTS – THREE PRIMARY RESEARCH OUTPUTS

The three primary research outputs, the property asset management board, a maturity matrix and route map to excellence are presented.

The property asset management board

The research team recommended the creation of a property asset management board (PAMB) as the primary vehicle to overcome fragmentation where departmental structures have decentralized arrangements with agencies, NDPB/ALBs and other sponsored organizations. In order to increase the level of strategic awareness, the research team recommended the PAMB should exist just below departmental management board level to ensure that policy development feeds directly into the formation of strategies for managing CCGE physical infrastructure assets. Policy development and then delivery are often seen as separate activities in government, and with limited overlap or consideration given to the impact on physical asset resource bases. The team encountered a sample of departments through fieldwork where a similar type of structure to the PAMB worked exceptionally well. However, this type of structure was not commonplace across government. The policy workshop identified and agreed in the order of 20–25 characteristics for the PAMB to address directly the fragmented nature of the management of CCGE assets. It necessitated bringing together the strategic and operational aspects of property asset management under one organizational unit with a clear policy, control, development and audit remit.

The PAMB would report vertically to ministers, permanent secretaries and to the OGC/HMT on property and fiscal related matters via the executive departmental management board. The expectation is that the PAMB would typically comprise in the order of 10 to 12 people including major business unit representatives with significant property holdings, the head of a consortium service provider(s) where any PFI/PPP structure operates, as well as IT, HR, finance and operational directors and representatives from the significant property centres, which in the case of the larger agencies would be the CEO or immediate alternative below that level. In line with models reviewed in the United States and Australia the research team recommended that the PAM function should be strengthened and recognized more fully at departmental management board level, with a designated board member having responsibilities and accountability for property asset management clearly identified and to act as the link between the departmental management board and the PAMB.

Under HM Treasury governance guidelines (HMT 2005) a head of department is charged with the stewardship of a department’s wider asset base and is held accountable for it to Parliament. However, depending on the manner in which departmental management boards are structured and operate, the head of department may designate and delegate the role and Lyons (2004b) proposed this should be finance directors. The fieldwork highlighted, however, that other models exist in practice within departments; the important point is that the named role has primary responsibility and is held accountable for leadership of the property asset management function, with a clear integrating mandate across departmental activities and arms-length bodies. That functional role should also include ensuring that an appropriate property asset strategy and associated plan has been developed, is updated, signed off and used as a management tool to manage the property portfolio over time within a department and also associated ALBs.

The PAM maturity matrix of excellence

A matrix of maturity for assessing excellence in PAM has been developed to act as a benchmark for the OGC, HMT and government organizations. It has a dual purpose: first, as a self-development tool to permit departments and ALBs to undertake their own assessments for continuous improvement; second, as the basis for independent audits of departments and ALBs to take place. The matrix consists of a set of levels of maturity and associated enablers and was derived from the Institute for Asset Management manual (IAM 2002), the DETR (2000) document *Building a better quality of life*, fieldwork, interviews, questionnaires and the policy workshop. The enablers identified are:

1. **Property asset management policy** dealing with the level an organization is at in terms of its policy towards PAM. This is a key enabler and includes aspects such as guidelines, KPIs and published targets.
2. **Roles and responsibilities** dealing with how an organization's property asset management decision-making structure is set up and managed, including explicit formal roles at tactical and strategic levels in the organization.
3. **Communication** dealing with how information regarding property asset management is handled in terms of data collection, and stakeholder, supply chain and management interactions.
4. **Asset management planning** dealing with the level at which an organization is at regarding formal property asset management planning. This includes the use, for example, of life cycle costing, risk management, benchmarking and meeting corporate objectives.
5. **Acquisition and disposal** deals with how acquisition and disposal of property within the organization is managed. It includes factors such as life cycle costing, health and safety, environmental issues, KPIs, risk management, procurement and social aspects.
6. **Operation and maintenance** deals with how the operation and maintenance of property assets within an organization is managed. It includes factors such as planned maintenance strategy, risk assessments, cost–benefit analysis, training, the use of O&M plans, responsibilities, ranking of property assets in terms of criticality, proactive implementation and evaluation against return on assets.
7. **Performance review and accounting** deals with how the review and accounting processes within an organization are managed. It includes the use of KPIs, property asset registers, training, financial management, roles and responsibilities as well as strategic reviews.
8. **Audit and review** deals with how the property asset management process is audited and reviewed, including skills and training needs, risk avoidance, use of technology and benchmarking of effectiveness and efficiencies.

The maturity matrix sets out transitions from 'unawareness' to 'excellence' (see Table 1 at the end of this paper). It was recognized during the research that the matrix needed further development and is the focus of a subsequent research study.

The route map to excellence

A key requirement from the study was the identification of strategic milestones to enable the OGC & HM Treasury to assess the level of embeddedness for PAM. The route map to excellence was developed through an intensive dialogue during the policy workshop. As a developmental programme the starting point is the base-lining element of the research and the anticipated end point at which OGC/HMT wished to see PAM embedded within the CCGE, with a significant number of departments and ALBs operating at or close to 'excellence' on the maturity matrix. Table 2 sets out the route map. It is linked within the maturity matrix introduced in Table 1. The key milestones identified in the research report are indicated below, with commentaries on current progress.

- In 2005 the first round of asset management plans (covering a broader spectrum than just physical assets) had been requested by HMT as part of the CSR2007 process. A further round of plans are required to inform CSR2007.
- In 2006 the maturity matrix and an agreed route map to excellence would be rolled out across central civil government. The route map was formally launched in November 2006 by the Chief Secretary to the Treasury in a publication entitled *High performing property* (OGC 2006). Further development work on the maturity matrix is set to be completed by July 2007 and launched at the OGC conference on 2 July. The route map identified the target date of March 2009 for all government organizations to set capability and skills standards against which they want to be measured, meaning that it needs to be rolled out across the CCGE during 2007–08.
- In 2007 the first formal assessment of PAM capabilities should be undertaken through an audit process of some 12–15 departments, agencies and NDPBs with major property holdings, and a random audit conducted on other smaller bodies. The OGC's recently published *Route map in high performing property* identifies that this is to take place in March 2009.
- By 2010 all government departments, agencies and NDPBs with major property holdings should have attained a profile on the maturity matrix consistent with a significant profile at Level 5 – excellence – to reflect their own circumstances and environment. The OGC published route map notes that all significant holders or users of property should have achieved Level 5 'excellence' by March 2011; this represents a core group of some 15–18 central government departments and ALBs.

Following the Lyons reports in 2004; the publication of the Leeds report on the OGC website in June 2006; a formal consultation period during the summer of 2006; and the publication of *High performing property* in November 2006; there is now an increased momentum in central government due to the impending CSR2007 review to embed property asset management across the CCGE. PAM is on the government's agenda to secure substantial monetary benefits through efficiency gains.

DISCUSSION AND CONCLUSIONS

There is an increasing international trend to adopt property asset management, as defined here, as a strategic function integrating business strategy with the operational use of property as a corporate resource. The UK central government is rolling out PAM across the civil estate; local government began addressing this some time ago.

There remain a significant number of challenges for the UK government associated not only with embedding PAM within a fragmented and highly decentralized government structure and asset base but including the implications of the costs and uncertainties surrounding the longevity of physical assets and the appropriate strategies for handling them. A few examples will demonstrate the point. First, fieldwork identified the significant impact of short-term government taskforces on space requirements for certain departments. Second, comments were made regularly during interviews that the expected lifespan of a government department could be at best two Parliaments, the most likely being no longer than one Parliament, typical figures quoted were three to five years. This was also a similar range reported in Australia. One department restructured during the timescale of the research study due to an unexpected political event. Again, this impacts on space requirements and the management of administrative as well as operational assets. Third, three generic strategies were encountered across the CCGE for handling the administrative estate in particular – leasehold, freehold and PPP/PFI. Some departments had a mix of all three and were operating with different asset ownership structures and different contractual and tenure timeframes. Fourth, some departments had the foregoing and a mix of operational and administrative assets, buildings-related and civil infrastructure, with investment requirements and whole life performance of those assets remarkably different. Finally, asset management literature typically argues that the long-term timeframe for considering property and infrastructure assets should be 25–30 years and beyond. It is, however, not quite so straightforward when confronted with the complexity of the CCGE, the influences and the timeframes noted here.

The conclusion from this research is that the only way to deal with this comprehensively is to embed property asset management as a strategic function within government departments at or just below executive management board level. With this in mind, this paper has presented three of the principal results from the report of the OGC-commissioned research forming part of the roll-out programme – the property asset management board, the maturity matrix and the route map to excellence. Lessons from the Australian experience indicate clearly that this is a medium- to long-term programme of activity. The OGC and HM Treasury have already set challenging targets for the short to medium term, not least in monetary terms but also in organizational terms. The second Lyons report notes the expectation is that central government organizations have no choice but to raise their game in property asset management and embed it within their normal ways of working.

REFERENCES

ANAO (1995) *Asset management.* Australian National Audit Office, Audit Report No. 27, 1995–96.

ANAO (1998) *Asset management.* Australian National Audit Office, Audit Report No. 27, 1998.

ANAO (2003) *Property management.* Australian National Audit Office. Report No. 19. 2003–04.

APCC (2001) *Asset management.* Australian Procurement & Construction Council Inc. Deakin.

Audit Commission (2000) *Hot property: getting the best from local authority assets*. Audit Commission National Report.

Barrett, P (2003) *An auditors view of commonwealth assets, including property management,* available at www.anao.gov.au/website.nsf/publications (accessed 12/3/06).

Blackie, N (2000) *Designing social research.* Cambridge: Polity Press.

Cabinet Office (2005a) *Classification of public bodies: guidance for departments.* Cabinet Office Guidance Note, August 2005.

Cabinet Office (2005b) *Public bodies 2005*, Material from the Public Bodies Online Directory. Agencies and Public Bodies Team, 31 March 2005.

DETR (2000) *Building a better quality of life: a strategy for more sustainable construction*. London: Department of the Environment and the Regions.

DPWS (2001) *Total asset management manual.* Sydney: NSW Department of Public Works and Services.

DTF (2005) *Strategic asset management framework for Western Australia.* Government of Western Australia, Department of Treasury and Finance.

Fawcett, P and Gay, O (2005) The centre of government – No. 10, the Cabinet Office and HM Treasury. House of Commons Research Paper 05/92, 21 December 2005.

FRPC (2004) *Guidance for improved asset management.* Federal Real Property Council, US Federal Government.

Gershon, P (2004) *Releasing resources to the front line.* London: HM Treasury.

HMT (2005) *Corporate governance in central government departments: code of good practice.* London: HM Treasury.

House of Commons (2005) *Managing resources to deliver better public services*, 25th Report of Session 2003–04 HC 181. Report, together with formal minutes, oral and written evidence. Ordered by the House of Commons, 7 April 2005.

IAM (2002) *International infrastructure management manual*. London: Institute of Asset Management.

IPD (2005) *Property benchmarking project OGC/51: final report for pilot phase*. Office of Government Commerce Report, 31 October 2005.

Lyons, M (2004a) *Well placed to deliver? Shaping the pattern of government service. An independent review of public sector relocation*. Report to the Deputy Prime Minister and Chancellor of the Exchequer. London: HMSO.

Lyons, M (2004b) *Towards better management of public sector assets: a report to the Chancellor of the Exchequer.* London: HMSO.

NAO (2003) *Managing resources to deliver better public services*. Report HC 61-I Session 2003–04, 12 December 2003.

NAO (2005) *Procurement in the culture, media and sport sector*. National Audit Office Report HC 596, Session 2005–06, 30 November 2005.

NAO (2006) *Getting the best from public sector office accommodation*. National Audit Office Report. June 2006.

NSWT (2004) *Total asset management manual.* New South Wales Treasury, September 2004.

OGC (2006) *Better measurement better management: effective management of the government estate*. Office of Government Commerce publication CP0134.

OGC (2006) *High performing property: routemap to asset management excellence*. Office of Government Commerce Publication CP0137.

OGC University of Leeds (2006) *improving property asset management in the central civil government estate.* Report produced by the University of Leeds for the Office of Government Commerce, April 2006.

OGC Howarth A. (2006) *A report on improving the capability and capacity of managing property assets in central civil government*. Report for the Office of Government Commerce and National School of Government, March 2006.

OGC University of Reading (2004) *Flexible working in central government: leveraging the benefits. A study of central government – flexible working practice*. University of Reading Report for the Office of Government Commerce, February 2004.

ONS (2005) Civil Service quarterly public sector employment statistics (PSES) as at 30 September 2005 (Quarter 3), available at www.civilservice.gov.uk/management/statistics/publications/xls/pses_q3_2005.xls (accessed 2 April 2006).

RICS (2002) *Property in business – a waste of space*. The Bootle Report for the Royal Institution of Chartered Surveyors by Capital Economies.

RICS (2005) *Asset management in local authorities.* London: Royal Institution of Chartered Surveyors.

Table 1: PAM maturity matrix (University of Leeds 2006)

Function Level	PAM Policy	Roles & Responsibilities	Communication	PAM Planning	Acquisition & Disposal	Operation & Maintenance	Performance Review & Accounting	Audit & Review
1. Unawareness	No written policy.	No staff resource active in management of assets.	No awareness of Asset Management & no dialogue with stakeholders.	Based on historical trends. Technical aspects only. Reactive	Ad hoc, informal. Price sensitive decision at line level.	Based on historical trend. Reactive maintenance. No condition assessment or performance monitoring.	Performance/cost management for major aspects only.	Reactive & unplanned.
2. Awareness	Informal guidelines setting out position on some Asset Management issues.	One or more individuals with adopted informal advocacy role at tactical level.	Some data requested routinely on Asset Management issues.	LCC for capital investment but no financial reporting. Some risk analysis. Approval procedures established	LCC, technical function, work practices, health & safety, environmental issues, O&M feasibility.	Maintenance strategy for major assets only. Asset reliability, risk assessment/cost benefit analysis considered. Training needs identified.	KPIs identified & communicated. Asset register in place. Training needs/no knowledge of financial management addressed. Process responsibilities established.	Skills & training needs identified. Well documented & prioritised processes & practices. Formal audit plans.
3. Knowledge	Formal statement setting out position on Asset Management.	Responsibility for PAM assigned to one manager.	Agreement with stakeholders on PAM objectives & targets. Data collected on most Asset Management issues.	Business oriented & performance based. Project evaluation & benchmarking. Prioritisation of investments	Full economic evaluation, LCC, performance, productivity indicators. Project management. Risk/sensitivity analysis. Integrated Procurement	Integrated financial/ O&M plans well documented. Specific costing activities. Responsibilities well defined. Project Management. Familiarity with AM practices.	Adequate skills. Well defined roles & responsibilities. Level/ cost of service regularly reviewed. System capability periodically reviewed.	Business & market oriented. Avoid unnecessary risk, use new technology, close monitoring.
4. Competence	Comprehensive internal statement, with indicators for some PAM issues.	PAM responsibilities within each business team.	Information on PAM issues reported to senior managers at strategic level & shared with key stakeholders.	PAM integral to business planning. Risk Management/ contingency plans target setting.	Value selection. Performance guarantee, support, technologies, financial, technical, risks & supplier credibility aspects.	O&M based business & performance objectives. Strategic ranking of assets. Risk Management practised. Proactive O&M.	Strategic review based on importance. Analyse trends/cause/ effect. Review support decision making. True cost, return on assets available.	System ownership embraced by staff. Participative decision making environment. Training completed.
5. Excellence	Published, with targets, reviews and promotion.	Overall responsibility with a senior manager at strategic level & regular progress reviews.	Regular dialogues with key stakeholders & supply chain, Asset Management performance major focus for reports.	Based on corporate objectives: financial/ marketing/ production. Risk Management. Industrial Relations. Modelling	Long-range strategic planning, social, environmental, technological, market forces.	Individual asset O&M strategy based on performance & evaluated against return on assets. Risk Management preventative maintenance.	Review process eminent & exemplary. Generates economic value & advancement.	Able to achieve benchmark efficiency & effectiveness. Independent audit available.

Table 2: A possible route map and action plan for implementing PAM across the civil estate (University of Leeds 2006)

	Period	Activities
Readiness for service	2006	• Engaging stakeholders. This should include heads of estates/permanent secretaries/ministers and should be carried out during the period between March and September 2006 and beyond. • Raise awareness of PAM at the QE2 Conference Centre event on 26 June 2006. • Launch road map for embedding and implementing property asset management during the period around September 2006. It is recommended that the launch does not take place until the stakeholder engagement exercise is complete. • Agree the direction, structure and process of PAM in the CSR process. • Obtain potentially the commitment from Treasury for seed-corn funding to enable an up-skilling campaign and any redundancy programme that may be required across estates functions due to continued rationalization. • Each department should produce a property asset strategy for the CSR process and this should be attached to FD and departmental plans; and should include sponsored bodies by October 2006. • By December 2006 there should be an agreed single document template for PAM plans forming part of the HMT requirement for asset management plans. • Adjustments agreed and made to departmental PSA targets, DEL and business planning processes. • Agreement that PAM forms part of the departmental capability reviews conducted by the Prime Ministers Delivery Unit.
	2007	• At the start of 2007 each organization should have achieved the milestone of the end of level two competences as described in the maturity matrix on the way to excellence in PAM. • Workshops should be held across government on the maturity matrix and discussions with Treasury Teams. • The National School for Government should commence embedding asset management in their training programmes. • PAM Plan template becomes part of the Spending Round 2007 process.
	Mid to late 2007	• An assessment should be made of the capabilities, structures and change programmes associated with PAM. There is a potential role for the NAO within this. Six to seven major departments, major agencies and six to seven NDPBs to be the main initial contributors across government. At this juncture a decision should be made on mandating the PAM process.
	End 2007	• Each organization should have achieved the milestone of the end of level three competences as described in the maturity matrix on the way to excellence in property asset management. • End of the period for 'readiness for service' in PAM. It should also be the commencement of the period of 'service delivery' for PAM.
Delivery	2008	OGC/Treasury: • Change agent role to support and challenge. • Peer review (department to department). • Priority review. • Annual stock take of whole direction of PAM in the civil estate. • Identify year-on-year targets sample basis (80:20) backwards and forward looking. Departments: • PAM fully embedded in business planning process. • Internal audit units should be undertaking annual stock takes of progress. • Department planning to meet Treasury targeted. • Shared service centres to be included within the process. • Responses to peer reviews and annual target reviews.
	2009–10	• A reassessment should be made of the capabilities, structures and change programmes associated with PAM by, for example, the NAO within in this timeframe. Six to seven major departments, major agencies and six to seven NDPBs to be the main initial contributors across government. This would also include a sample of a wider population of sponsored bodies. • Ongoing implementation and embedding of PAM. • Post implementation review/policy assessment e.g. reporting to the Prime Minister's office. • At the end of 2010 each organization should have achieved the milestone of the end of level five competences as described in the maturity matrix on the way to excellence in PAM, reflecting a profile of cells within the matrix to reflect the nature of each organization.
	2011	• Review and refresh for the next step in PAM – April 2011.

OPTIMAL AND DYNAMIC ASSET MANAGEMENT IN INFRASTRUCTURE SECTOR

Tiina Koppinen[1] and Tony Rosqvist[2]

[1]*VTT Technical Research Centre of Finland, PO Box 1300, FIN-33101 Tampere, Finland*
[2]*VTT Technical Research Centre of Finland, PO Box 1000, FIN-02044 VTT, Finland*

Road, rail and water/sewerage networks are vital to the national economy. Reduction in public financing together with increasing use of networks, urge infrastructure managers to optimize their networks focusing on overall cost-effectiveness of their operations. Decision-making in asset management should be able to ensure long-term economic efficiency and optimal service levels. However, often decision-making in infrastructure management under uncertainty is far from optimal, reliable and flexible. This is why a simplified asset management decision-making method was developed for the infrastructure sector. The method aims at assisting infrastructure managers in optimizing the life cycle profiles of their assets through selection of an optimal maintenance, repair and rehabilitations project portfolio. The method applies the analytical hierarchy process and real option ideology. The developed systematic and easy-to-apply method fills the void between strategic and operative decision-making methods facilitating management of multiple investments at the local network management level.

Keywords: asset management, decision analysis, facilities management, infrastructure management, project appraisal.

INTRODUCTION

Infrastructure networks are vital to the national economy. As the economic and technical lifetime of the networks are long, numerous rebuilds, replacements and expansions take place during the lifetime highlighting the importance of Asset Management (AM). Reduction in public financing together with increasing use of the networks, urge infrastructure managers to optimize their networks focusing on overall cost-effectiveness of their operations. For AM to live up to the expectations, it has to meet four key challenges: (a) alignment of strategy and operations with stakeholder values and objectives; (b) balancing of reliability, service-level, safety, and financial considerations (Schneider *et al*. 2006); (c) ensuring optimal packaging and timing of works, and adequate competition; and (d) promoting market development (Koppinen and Lahdenperä 2004). Also, often cited objectives include maximizing the net benefit to the public, efficient use of resources, and early usage of the built facilities (Hsieh and Liu 1997). However, often decision making in infrastructure development and operation under uncertainty is far from optimal, reliable, and flexible (Zhao and Chung 2006). Approaches to municipal infrastructure management tend to be centred upon annual project execution. Simply executing existing backlog fails to consider projects in an appropriate context (Garvin *et al*. 2000).

[1] tiina.koppinen@vtt.fi

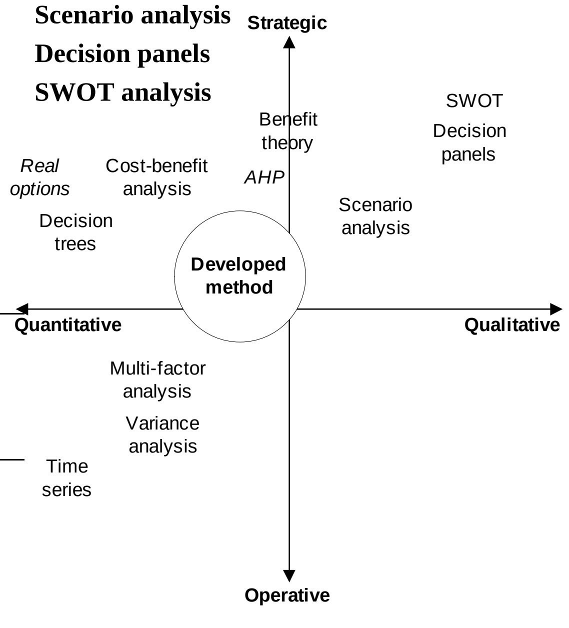
In these circumstances, it was considered important to develop a structured decision making method for infrastructure managers that would facilitate evaluation of project alternatives in order to find the most cost-effective Maintenance, Repair and Rehabilitation (MR&R) projects for implementation. This was done as a part of a research project called “Strategic framework for asset management in capital-intensive industries”. The paper outlines the work done for the infrastructure sector by starting with a list of existing decision making methods. Next, the methods are selected for the tool development and the developed, strategic framework is described. Finally, the developed, simplified Project Portfolio Selection Method (PPSM) is discussed and conclusions made.

DECISION MAKING METHODS

Different decision making methods have been developed to assist managers in decision making. Table 1 lists both strategic and operative decision making methods that aim at taking into consideration uncertainties. The Analytical Hierarchy Process (AHP) is adopted as the primary method for selection of an optimal project portfolio. AHP is easily understood and already applied in many decision making tools. AHP is enhanced with Real option thinking which best recognizes that the optimality of a certain project portfolio may depend on the level and type of uncertainty in the operating environment.

Table 1: Methods and techniques that assist decision making in uncertain circumstances

Quantitative methods	**Qualitative methods**
Decision analysis - Benefit theory/decision trees - Quantitative risk analysis - Models for stochastic dominance (FSD, SSD, TSD) - Models for information value - Markov models - Multi-goal optimization - Multi-criteria decision-making (e.g. AHP)	**Scenario analysis** **Decision panels** **SWOT analysis**
Data analysis – Time series – Multi-factor analysis – Variance analysis	
Economic quantitative methods - Analysis of uncertainties existing in investment opportunities (e.g. NPV simulation,, *Real Option theory*) - Competition theory models - Game theory models - Demand/supply models, benefit-theory - Cost-benefit analysis	



The embedded figure positions the methods in terms of their strategic- and quantitative-nature. The circle in the figure shows the void, which the developed method should fill.

Real options

Real options approach models infrastructure management processes as contingent decision making and is capable of yielding optimal solutions in light of multiple uncertainties (Zhao and Chung 2006). Real option analysis recognizes that the flexibility inherent in capital projects has value. An option to expand, defer, downsize or abandon a major capital investment allows an organization to respond to strategic and competitive opportunities rather than remaining locked into a fixed course of action. Options may be divided into two groups: flexibility and growth options (Du *et al*. 2006). However, valuation of these real options and associated financial option-based calculations are often considered overly complicated. It has been suggested that few practitioners truly understand or use the real options approach (Alkaraan and Northcott 2006). This is why an easy-to-use and reliable-enough tool is needed to assist infrastructure managers in selecting optimal projects in an uncertain environment.

AHP

The AHP, a multiple-attribute decision making technique, developed by Saaty (1980) provides a flexible and easily understood way of analysing complicated problems. AHP allows subjective as well as objective factors to be considered in the decision making process and it can handle criteria that may be conflicting. Additionally, AHP forms a systematic framework for group interaction and group decision making which is often utilized in project evaluation.

INVESTMENT PORTFOLIO EVALUATION

The asset manager must select optimal projects to the MR&R project portfolio. The optimal project portfolio depends on the operating environment. For an organization operating in a stable operating environment, the success criteria of AM may relate to reliability of service quality and speed of response set against continuous improvements in cost efficiency. However, when uncertainty in the operating environment increases, speed and appropriateness of change become increasingly relevant elements of competitiveness (Kelly *et al*. 2002). The developed method pursues to incorporate this type of consideration as an inherent part of optimal MR&R project selection. The project evaluation process is divided into two consecutive evaluations: If the project passes the pre-screening phase, it enters into the prioritization. In selecting the right asset portfolio the asset manager needs to asses, among others, alternatives' fit into the strategy, resource requirements, inherent flexibility, and resulting serviceability, operability and maintainability of the network locally and as a whole (Figure 1).

Project pre-screening

When AHP and real options are integrated, a new, simplified method for assessing investment opportunities at the local network management level is developed. Quantitative and qualitative criteria listed in Figure1 are more systematically grouped according to Figure 2: V) Value creation (~benefits); R) Resource-availability (~costs); and F) Flexibility provided by the alternatives in case of future changes (~real options). The level of Value creation is determined by whether the evaluated alternative: (1) fits into the organization's strategy; (2) contributes to the organization's capabilities promoting continuous improvement; (3) provides important stakeholders with added value; (4) enhances safety, reliability and service-level of operations; and (5) promotes market and industry development. Resource-availability is determined based on whether: (1) public financing is available; (2) other sources of funding are available; (3) in-house expertise is available; (4) industry has appropriate capabilities; and (5) market situation enables adequate supply and competition in the industry (Koppinen and Rosqvist 2007). Future flexibility is determined based on the availability and usability of real options inherent in the alternative.

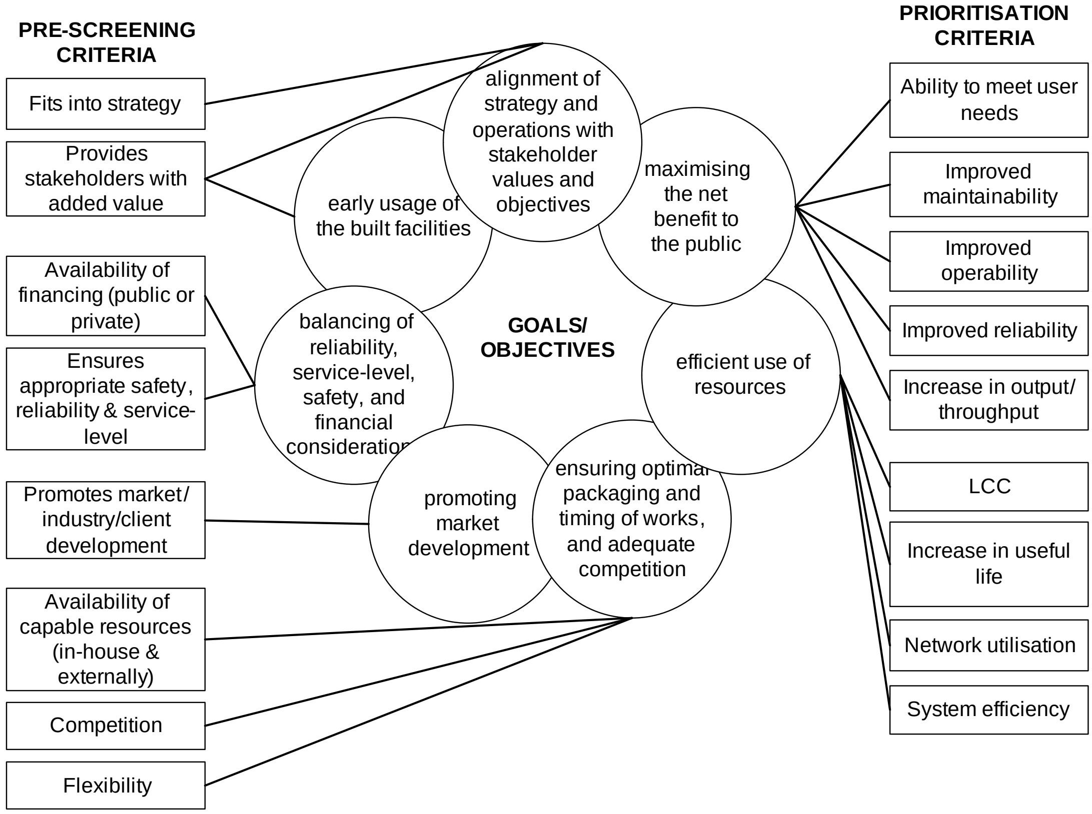


Figure 1: Turning client objectives in the infrastructure sector into the evaluation criteria

The underlying principle is to establish relative weights (w_i) of the above criteria and sub-criteria using pair-wise comparison based on AHP-method (see Table 3). The recommended scale used for making comparisons is 1–9 (Saaty 1980). Generally, the more critical the criterion is in relation to the other criteria, the higher it should be weighted. For example, the weighting of the future flexibility depends on the level of uncertainty existing/expected in the operating environment; the more uncertain environment, the more valuable flexibility is, the higher its weight should be.

As the infrastructure managers should pursue objectivity in assessing somewhat subjective factors, the sub-criteria scoring is determined based on Table 3. This system reduces effect of personal preferences. For example, R3 – In-house expertise exists: If expertise required by the alternative exists in-house, but is located in another regional office, internal co-operation is necessary in order to utilize the expertise. If earlier experiences in cooperation have been successful, the score would be 8. On the other hand, if the organization has no history of co-operation between the different regional offices, initial inefficiency may be experienced. In this case, the score should be 7.

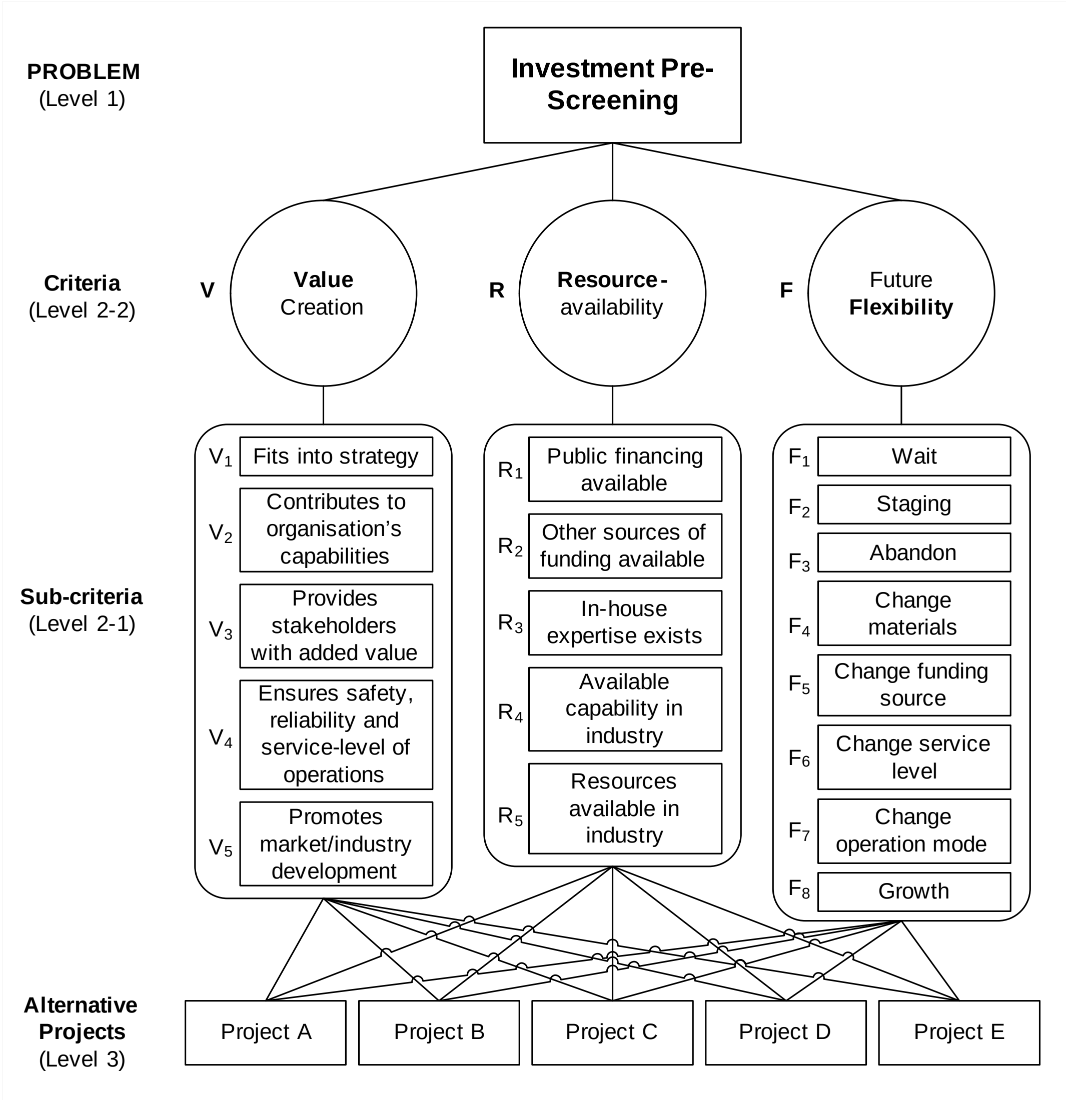


Figure 2: Investment pre-screening using AHP and taking into consideration real options

Table 2: Final importance of criteria and preferences of alternatives in pre-screening

Criteria	**Value Creation**					**Resource-availability**					**Future Flexibility**					**Total ***
Relative weights	w_V (weights through AHP)					w_R					w_F**					(sum=1)
Sub-crit.	V1	V2	V3	V4	V5	R1	R2	R3	R4	R5	F_i	F_i	F_i	F_i	F_i	
Weights	w_{V1}	w_{V2}	w_{V3}	w_{V4}	w_{V5}	w_{R1}	w_{R2}	w_{R3}	w_{R4}	w_{R5}	w_{Fi}	w_{Fi}	w_{Fi}	w_{Fi}	w_{Fi}	(sum=3)
Project A	a_{V1}	a_{V2}	a_{V3}	a_{V4}	a_{V5}	a_{R1}	a_{R2}	a_{R3}	a_{R4}	a_{R5}	a_{Fi}	a_{Fi}	a_{Fi}	a_{Fi}	a_{Fi}	A_{tot}
Project B																B_{tot}
Project C																C_{tot}
Project D																D_{tot}
Project E																E_{tot}

* $X_{tot} = w_V*(?w_{Vi}*x_{Vi})+w_R*(?w_{Ri}*x_{Ri})+ w_F*(?w_{Fi}*x_{Fi})$, i=1…5 (Flexibility: i=1…8, of which 5 most important options selected), x=a,b,c,d,e valued according to table xx; 1= X_{tot}=10

** The more uncertainties exist in the operating environment; the higher weight should be given to Future Flexibility.

Instead of complicated option-based valuation methods, flexibility provided by different real options is valued based on the option costs (OC) involved with the options, since flexibility typically comes at a price and is only valuable as a hedge against the uncertainty (Du *et al*. 2006). Here, strategic real options are determined based on the uncertainties existing in the operating environment. Score depends on the level of OC involved with the option when compared to an alternative without this option. For example: when the level of competition in the industry is uncertain, valuable real options are waiting, staging and changing of operation mode. If an alternative provides an option to implement the project in stages, and it may be expected that the competition level is significantly improved by the phase two, the staging option is valuable. Now it is assed how much more this alternative costs when compared to an alternative without this option. If OC is approximately 7% of project cost, the score would be 5, while OC of 6% would result in the score of 6.

Table 3: Valuation of the pre-screening criteria (scale 1…10)

Criteria		**Score**				
		1–2	**3–4**	**5–6**	**7–8**	**9–10**
V1	Fits into strategy	negligible	fulfils fraction of strategy	fulfils basic principles of strategy	fulfils most of strategy	fulfils strategy
V2	Contributes to organisation's capabilities	negligible	improvement trivial	improves existing capabilities	broadens capabilities	builds new strategic capabilities
V3	Provides stakeholders with added value	negligible	some	average amounts	more than average	significantly
V4	Ensures safety, reliability & service-level of operations	negligible	improved to some extent	probability of failures <7%	probability of failures <5%	probability of failures <2%
V5	Promotes market/industry development	negligible	to some extent	industry cooperation increased	industry innovativeness improved	significantly
R1	Public financing available	none	minor part	partially	adequate/ total funding	abundantly
R2	Other sources of funding available	none	one source – partial funding	two sources – partial funding	adequate funding available	abundantly
R3	In-house expertise exists	negligible	requires long-term planning and training	requires some training	requires internal co-operation	expertise readily available
R4	Available capability in industry	negligible	requires long-term planning and training	requires some training	requires industry co-operation	capability readily available
R5	Resources available in industry	negligible	requires long-term planning and much funding	requires training or waiting for completion of current projects	requires good co-ordination/ management	resources readily available
Select max. 5 strategic real options based on uncertainties in the operating environment (Fig. 2):						
F_i	n.n.	significant option costs (OC) involved	OC 10% of project cost	OC 7% of project cost	OC 4% of project cost	negligible OC involved

Finally, projects that provide x_{tot} values greater than a certain pre-determined threshold value may be selected as a promising set of projects. To visualize the above analysis, the results are drawn into a diagram shown in Figure 3. Here x-axis depicts the score of resource requirements (≈ costs), while y-axis denotes the score of value generation (≈ benefits). The size of the symbol depicts the score of flexibility. Projects in the up most, right-side square should be implemented, while projects in the lowest left-side square should be declined. Other projects above the diagonal could be implemented, if resources were available. No further analysis would be necessary. However, as resources are often deficient, these potential projects should be evaluated more thoroughly in order to implement truly the best projects. This is done through project prioritization. Projects underneath the diagonal should be omitted from the evaluation and declined unless magnitude of uncertainty and flexibility provided by the alternative justify a further evaluation of an alternative.

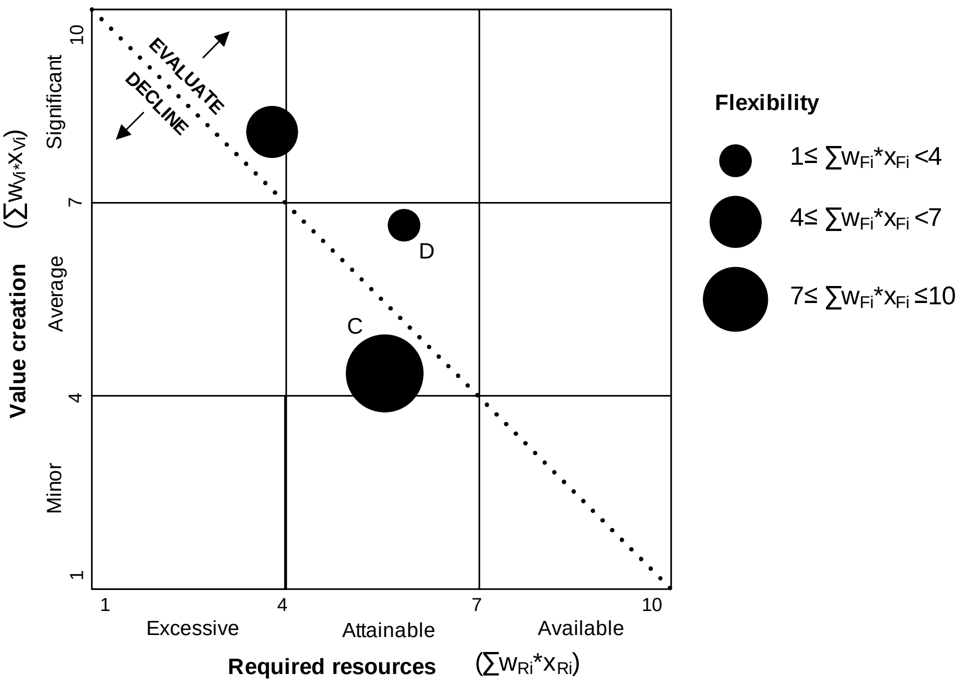


Figure 3: Selection of the potential alternatives (Koppinen and Rosqvist 2007)

Project prioritization for optimal portfolio

In order to optimize the MR&R project portfolio, a more comprehensive assessment is performed on the pre-selected alternatives (Koppinen and Rosqvist 2007). The method used is similar to the pre-screening (Figure 4), but now criteria used are divided into following groups: (1) improvement in maintainability of the asset; (2) service improvements produced; and (3) optimized life cycle cost (LCC) of the asset. The first two criteria determine the level of overall benefits of the projects, while the third criterion determines the true life cycle cost of the project (Table 4). The level of improvement in maintainability is determined by how the evaluated alternative impacts on (1) network or (2) system reliability and (3) maintainability of the network; and how it affects (4) the operation and (5) the remaining life of the network. Level of service improvement is determined based on: (1) increases in throughput; (2) network utilization level; (3) system efficiency; (4) reliability of service; and (5) ability to meet user needs. Scoring of the benefits criteria is performed based on Table 5.

The results of the prioritization are drawn into a diagram shown in Figure 5. Here x-axis depicts the LCC of the project, while y-axis denotes the scored benefits of the project. The size of the symbol depicts the flexibility provided by the investment alternative (determined in project pre-screening). Again projects above the diagonal should be selected to the project portfolio, while projects underneath the diagonal should be declined. The diagonal can be moved perpendicularly depending on the availability of resources. The idea is to position the diagonal so that the level of available resources is equal to LCC of the project portfolio (= $\sum LCC_i$, i= A, B…).

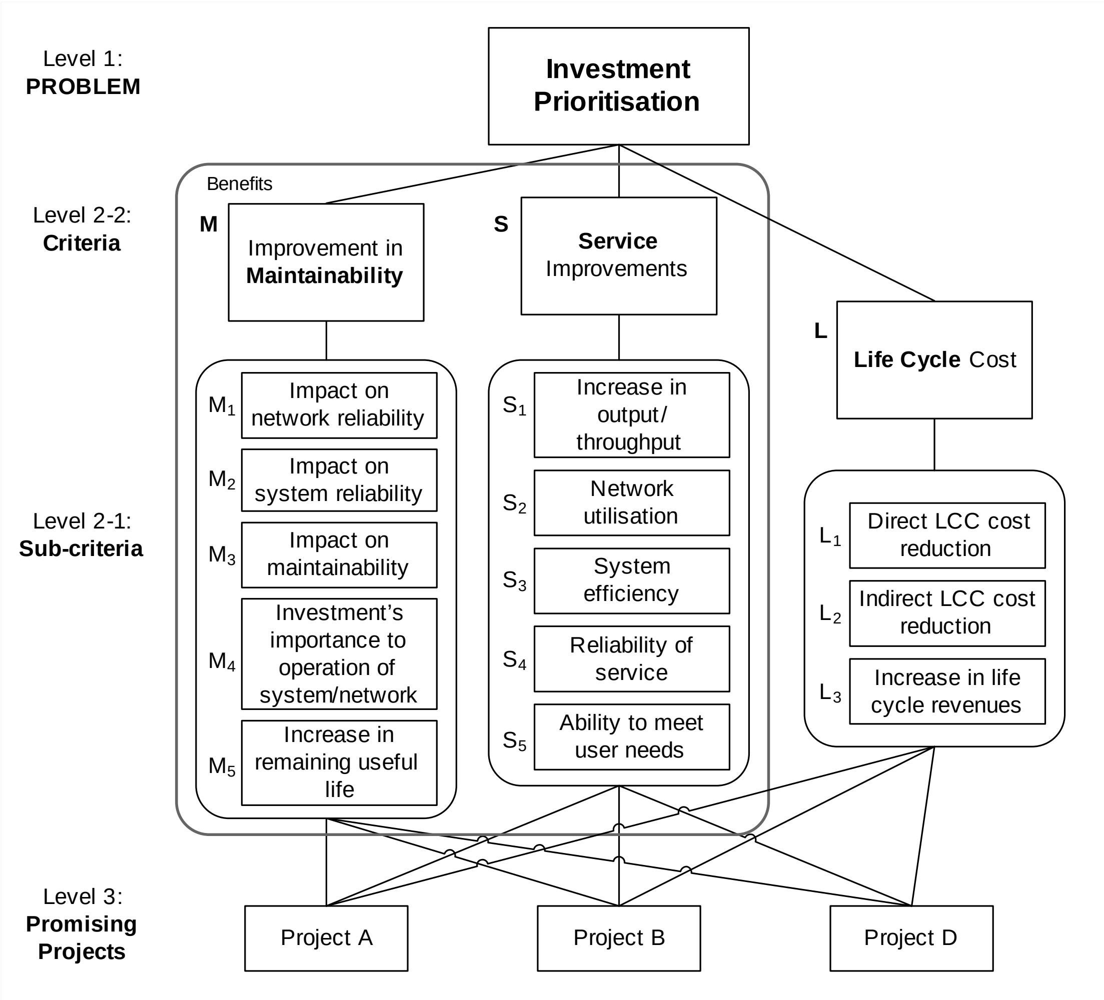


Figure 4: Investment prioritization using AHP in order to optimize the network's life cycle profile

Table 4: Final importance of criteria and preferences of alternatives in project prioritization.

Criteria	**Improvement in Maintainability**					**Service Improvements**					**Total Benefits**	**Life Cycle Cost**		
Weights	w_M (weights through AHP)					w_S					(sum=1.0)			
Sub-criteria	M1	M2	M3	M4	M5	S1	S2	S3	S4	S5		L1	L2	L3
Weights	w_{M1}	w_{M2}	w_{M3}	w_{M4}	w_{M5}	w_{S1}	w_{S2}	w_{S3}	w_{S4}	w_{S5}	(sum=2.0)			
Project A	a_{M1}	a_{M2}	a_{M3}	a_{M4}	a_{M5}	a_{S1}	a_{S2}	a_{S3}	a_{S4}	a_{S5}	A_{tot}	LCC_A		
Project B											B_{tot}	LCC_B		
Project D											C_{tot}	LCC_C		

$X_{tot} = w_M*(\sum w_{Mi}*x_{Mi})+w_S*(\sum w_{Si}*x_{Si})$, i=1…5, x=a,b,c according to table xx; $1\leq X_{tot}\leq 10$

Table 5: Valuation of the prioritization criteria (scale 1…10)

Criteria		Score 1–2	3–4	5–6	7–8	9–10
M1	Impact on network reliability	negligible	improved to some extent	probability of failures <5%	probability of failures <3%	probability of failures <1%
M2	Impact on system reliability	negligible	improved to some extent	probability of failures <5%	probability of failures <3%	probability of failures <1%
M3	Impact on maintainability	negligible	slightly facilitated	facilitated to some extent	maintainability better than average	significantly improved
M4	Importance to operation of system/network	negligible	operation slightly facilitated	operation facilitated to some extent	operation more efficient than average	strategic/ significant
M5	Increase in remaining useful life	negligible	25%	50%	75%	100%
S1	Increase in output/ throughput	none	meets partially projected increases in future demand	meets projected average increases in future demand	meets projected increases in future demand	meets projected extreme increases in future demand
S2	Network utilisation	significant over capacity or severe problems during peak utilisation	mostly inefficient	some over capacity or average problems during peak utilisation	mostly efficient	optimal
S3	System efficiency	current level or worse	increased by 10%	increased by 15%	increased by 20%	increased by 25%
S4	Reliability of service	current level or worse	failures reduced by 10%	failures reduced by 35%	failures reduced by 50%	failures reduced by 65%
S5	Ability to meet user needs	negligible	meets minor user needs	meets primary user needs	meets most user needs	meets all user needs

DISCUSSION

The developed PPSM is a generic, theoretical model for the infrastructure sector as a whole. It has not been tested in real projects, and the criteria applied aspire to be general for all infrastructure sectors. In the future research, the model will be applied to different infrastructure sectors in order to refine the model and criteria to different decision making situations. However, it is expected that in most cases a different set of criteria may be applied without changing the overall structure of the method. When different set of criteria is used, care must be taken in order to avoid double counting. Also scoring of the sub-criteria is purely theoretical and may not provide the best possible ranges for decision making in different infrastructure sectors. Thus, the scoring should be revised according to the sector-specific experiences before applying the method.

In further research, evaluation of the flexibility-level provided by the alternatives will also be looked at in more detail. Currently, flexibility is presented in the diagrams as a circle with a purely imaginative and descriptive radius. However, the model could be further developed by giving the flexibility a symbol, whose radius depicts better the true value and/or option cost of real options/flexibility.

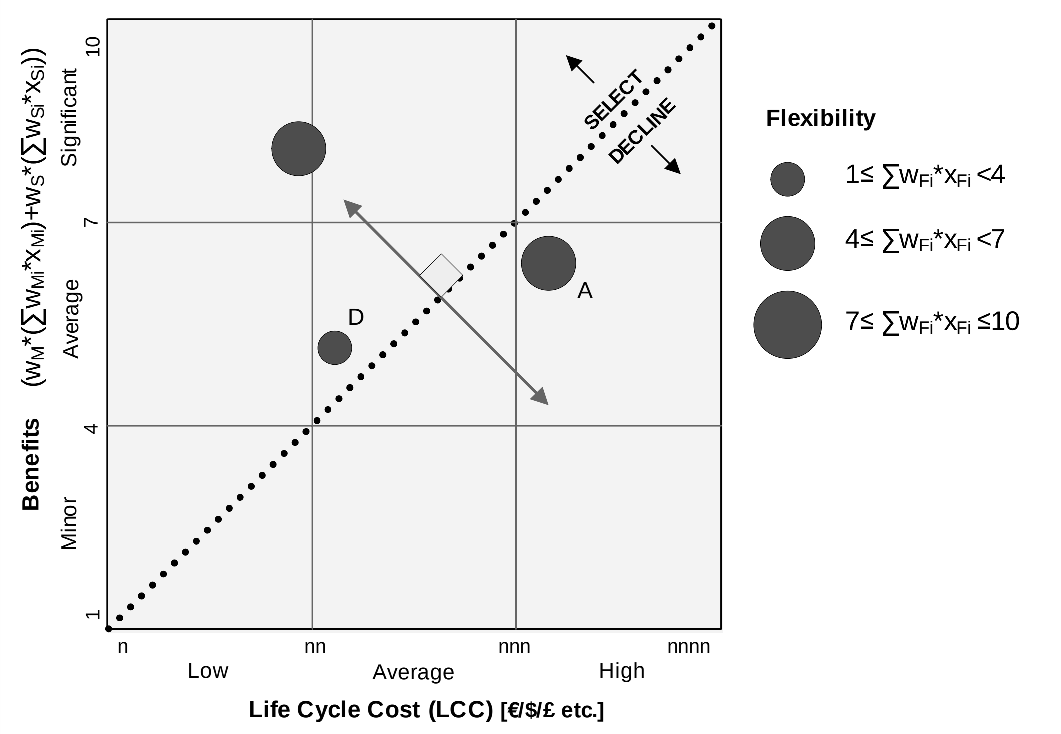


Figure 5: Selection of the project portfolio for implementation (Koppinen & Rosqvist 2007)

CONCLUSIONS

One of the biggest challenges for any public organization today is, how to prioritize projects to maximize the benefit of optional funding. The objective of the developed decision making method was to pre-screen investment options and to evaluate project alternatives in order to find the most cost-effective maintenance, repair and rehabilitation projects for implementation. (With the suggested pre-screening analysis, the asset manager can determine the order of preference of alternative projects, while the prioritization analysis determines the optimal MR&R project portfolio.) The developed method fills its intended purpose as an easy-to-apply link between strategic and operative decision making, supporting decision-making related to the management of network condition and functionality through optimal MR&R project portfolio planning.

REFERENCES

Alkaraan, F and Northcott, D (2006) Strategic capital investment decision making: A role for emergent analysis tools? A study of practice in large UK manufacturing companies. *The British Accounting Review*, **38**, 149–73.

Du, J, Jiao, Y-Y and Jiao, J (2006) A real-option approach to flexibility planning in reconfigurable manufacturing systems. *International Journal of Advanced Manufacturing Technology*, **28**, 1202–10.

Garvin, J M, Wooldridge, S C, Miller, J B and McGlynn, M J (2000) Capital planning system applied to municipal infrastructure. *Journal of Management in Engineering*, September/October, 41–50.

Hsieh, T-Y and Liu, H-L (1997) Multistage heuristic approach for solving infrastructure investment decision problems. *Journal of infrastructure systems*, **December**, 134–42.

TOWARDS EFFECTIVE LEADERSHIP IN CONSTRUCTION STAKEHOLDER MANAGEMENT

Ezekiel Chinyio[1] and Deborah Vogwell[2]

[1]*School of Engineering and the Built Environment, University of Wolverhampton, Wulfruna Street, Wolverhampton WV1 1SB, UK*
[2]*National Consultancy Unit, English Partnerships, 414–428 Midsummer Boulevard, Central Milton Keynes, Buckinghamshire MK9 2EA, UK*

Nowadays construction clients are multifaceted and often deal with a large configuration of stakeholders in the course of a project. These stakeholders often include owners, users, project managers, facilities managers, designers, subcontractors, suppliers, process and service providers, competitors, banks, insurance companies, media, community representatives, neighbours, customers, regional development agencies and the natural environment. Stakeholders have claims, rights and expectations that impact on corporate governance, processes and outcomes, and in this regard can undermine the objectives of a construction project. The ability of a project team to identify and map stakeholders accurately informs both the relationship with the latter and project success. Meanwhile, stakeholders must be motivated proactively to behave in ways that support the objectives of a project and this can be achieved by using specific engagement strategies. A research that evaluated the practice of effective construction stakeholder management informs this article. Twelve interviews with key project stakeholders were conducted. A qualitative design was employed in the research, which was carried out by means of the grounded theory methodology. The data were evaluated by means of content analysis. The empirical findings identified the strategies and tactics for managing stakeholders; however, this article dwells on only one strand of the findings, i.e. that effective leadership of stakeholders can help harmonize their goals and prevent potential conflicts. The other findings of the research are disseminated elsewhere.

Keywords: client, corporate governance, leadership, risk management, stakeholder management.

INTRODUCTION TO STAKEHOLDER MANAGEMENT

A stakeholder is an individual with an interest or a share in an undertaking (Weiss 2006). The dimensions of interest are almost open-ended hence the checklist of stakeholders in most undertakings is often long. In construction projects, the stakeholders will often include (Newcombe 2003; Smith and Love 2004): clients (both owners and users); project managers; facilities managers; designers; shareholders; legal regulators; employees; subcontractors, suppliers and process or service providers; competitors; banks; insurance companies; community representatives, neighbours, general public; government/local authority; visitors and customers (both current and potential); regional development agencies, etc. The stakeholders in a project can be divided into (Calvert 1995; Winch and Bonke 2002):

- internal stakeholders (those who are members of the project coalition or who provide finance); and
- external stakeholders (those affected by the project in a significant way).

[1] e.chinyio@wlv.ac.uk

Similar classifications are: inside and outside stakeholders (Newcombe 2003); direct and indirect (Smith and Love 2004); primary versus secondary, social versus non-social and core, strategic or environmental (Carroll and Buchholtz 2006).

Stakeholders have power to be either a threat or a benefit to an organization (Gibson 2000). They can trigger project schemes (Orndoff 2005) and can support or obstruct an ongoing project (Vogwell 2002). Organizations often depend on external stakeholders for resources which gives the later a leverage (Frooman 1999). The argument is: stakeholders have claims, rights and expectations that ought to be honoured and not taken lightly (Carroll and Buchholtz 2006). Thus, stakes must be managed in each project to avoid any of their influences that could be contrary to a firm's objectives. Conversely, business endeavours and indeed construction projects, affect stakeholders. So it is a tit for tat affair. Businesses must recognize their stakeholders and manage them; and vice versa.

Differing stakes are a major source of conflict hence it is worthwhile to manage stakeholders in most undertakings. A research that examined stakeholder management in construction is reported in the paper. Although several findings were established in the research, size restriction warrants the discussion of one main issue in this paper, i.e. the need to develop more effective leadership in construction project delivery.

The next section reviews stakeholder theory. After that, a research that informs this paper is introduced along with its methodology. The outcome of the research with respect to leadership is then discussed before wrapping up.

ASPECTS OF THEORY

Stakeholder management involves managing relationships in order to motivate stakeholders to behave in ways that support a firm's objectives. The art of stakeholder management is about creating the most positive environment in which to develop a project (Vogwell 2002). It has been argued that corporations have a moral obligation to their stakeholders and that their policies should incorporate stakeholder inclusion with auditable board and executive level responsibilities for stakeholder relations (Wheeler and Sillanpää 1997).

Even if all stakeholders have all the good intentions, and they often do, their large number in a given project warrants their management because the pursuit of their individual objectives may not necessarily be congruent. It also demands a proactive approach in dealing with stakeholders as opposed to being reactive.

Shareholders constitute one set of internal stakeholders who have invested in a firm in expectation of rewards in terms of dividends, share appreciation and capital repayments (Doyle and Stern 2006). Shareholders have an influence on the objectives of an organization. Likewise, other stakeholders can influence the pursuit of an organization's objectives (Freeman 1984). While shareholders can influence an organization from within, most other stakeholders often influence it from the outside. The management concerns of a company are in someway sandwiched by its shareholders and stakeholders. Both shareholders and stakeholders place demands on the management of a company and it is worthwhile to address both sets of demands. The ideal is to strike a balance where the objectives of a business are achieved while satisfying stakeholders, that is, a win-win approach (Carroll and Buchholtz 2006). The discussions in this paper are however limited to stakeholder issues.

A stakeholder management approach takes many factors into account, e.g. moral, political, technological and economic interests (Weiss 2006). Three approaches are useful for dealing with stakeholders, i.e. (Goodpaster 1991):

1. *Strategic approach*: This approach allots shareholders' profit a greater priority above the interests of other stakeholders.
2. *Multifiduciary approach*: This assumes a fiduciary responsibility to stakeholders, allotting them equal stakes with shareholders.
3. *Stakeholder synthesis approach*: This approach assumes a moral but non-obligatory responsibility to stakeholders, e.g. dealing with them ethically.

Stakeholder management theory evolved from business management and aims to describe, understand, analyse and manage stakeholders. Its theory is that an organization has relationships with many constituent groups and that it can engender and maintain the support of these groups by considering and balancing their relevant interests. To any organization, therefore, the key considerations in practical stakeholder management should include the following (Carroll and Buchholtz, 2006):

1. Who are our stakeholders?
2. What are their stakes?
3. What opportunities do they present?
4. What challenges or threats do they present?
5. What responsibilities do we have towards our stakeholders?
6. What strategies or actions should we use to engage our stakeholders?

The sixth point is significant and loaded. It considers such aspects as;

- Should we deal directly or indirectly with our stakeholders?
- Should we be aggressive or defensive in dealing with stakeholders?
- How and when should we accommodate, negotiate, manipulate or resist the overtures of our stakeholders?
- How and when should we employ a combination of the above strategies or pursue a singular course of action?

It is widely acknowledged that Freeman (1984) introduced modern stakeholder theory to the business sector, and explicitly linked stakeholder interests to corporate strategy. A major purpose of stakeholder theory is to help corporate managers understand their stakeholder environments and manage them more effectively. A larger purpose is to help corporate managers improve the value of the outcomes of their actions while minimizing any harm to stakeholders. In essence, stakeholder theory concerns relationships between corporations and their stakeholders (Logsdon and Wood 2000). Stakeholder management practice is now underpinned on ethical, social and economic considerations.

Stakeholder management is useful to procurement in general and has been fostered in several disciplines, e.g. land remediation, forestry; business marketing; IT; electronics industry; hospitals; automotive industry, etc. Construction practice had embraced it and is now coming to terms with its promotion. Stakeholder management is being researched in both construction and other disciplines (Kolk and Pinkse 2006).

The key principles of stakeholder management (in Table 1 below) were first proposed by Max Clarkson who became legendary for his early support of the stakeholder concept. The principles emerged organically after an international group of management scholars, including Clarkson himself, explored the role of the large corporation in modern, highly interdependent economies. Their goal was to develop a broad concept of the firm as a vehicle for advancing the interests of multiple and diverse stakeholders. The principles thus incorporate a variety of perspectives and provide a template and guide to organizations for managing their stakeholders (Donaldson 2002).

Understanding stakeholders

Stakeholder management involves identifying and classifying stakeholders, thus facilitating both initial and subsequent engagement with them in a timely, planned and coordinated manner. This engagement involves identifying different categories of stakeholders; gathering information about them; identifying their missions in a project; determining their strengths and weaknesses; identifying their strategies; predicting their behaviour and developing and implementing a stakeholder management strategy (Cleland 1999). The classification of any set of stakeholders should identify those that are (less) critical at a particular point of time.

A twofold matrix is often used to map stakeholders on the basis of:

1. the power they can exert on a project or firm;
2. their level of interest in an undertaking.

Relatively, minimal effort is required in satisfying stakeholders with little interest in a project, whereas greater effort is required in keeping stakeholders with high interests happy (see Figure 1).

Table 1: Principles of stakeholder management (www.mgmt.utoronto.ca/~stake/Principles.htm)

Principle	**Stipulation – that managers should:**
No. 1	*Acknowledge* and actively *monitor* the concerns of all legitimate stakeholders, and should take their interests appropriately into account in decision making and operations.
No. 2	*Listen* and openly *communicate* with stakeholders about their respective concerns and contributions, and about the risks that they assume because of their involvement with the corporation.
No. 3	*Adopt* processes and modes of behaviour that are sensitive to the concerns and capabilities of each stakeholder constituency.
No. 4	*Recognize the interdependence* of efforts and rewards among stakeholders, and should attempt to achieve a fair distribution of the benefits and burdens of corporate activity among them, taking into account their respective risks and vulnerabilities.
No. 5	*Work cooperatively* with other entities, both public and private, to ensure that risks and harms arising from corporate activities are minimized and, where they cannot be avoided, appropriately compensated.
No. 6	*Avoid altogether* activities that might jeopardize inalienable human rights (e.g. the right to life) or give rise to risks that, if clearly understood, would be patently unacceptable to relevant stakeholders.
No. 7	*Acknowledge the potential conflicts* between (a) their known roles as corporate stakeholders; and (b) their legal and moral responsibilities for the interests of stakeholders, and should address such conflicts through open communication, appropriate reporting, incentive systems and, where necessary, third party review.

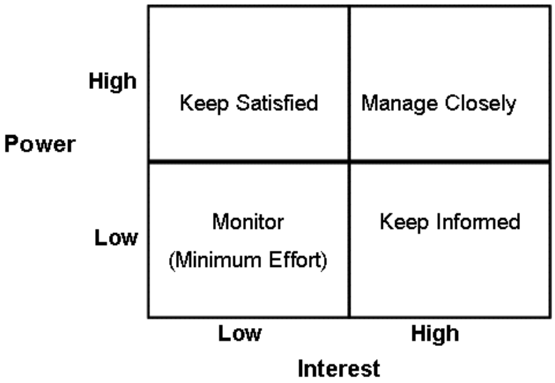


Figure 1: Power-Interest grid

In addition to the power–interest dimension Newcombe (2003) considered a power-predictability matrix. In this regard, stakeholder management should be able to identify those that can spring a surprise in terms of making a demand on or exercise power in a project. When things are progressing well with an organization and its stakeholders, it does not necessarily mean that a stakeholder cannot place a sudden and unnecessary demand on their project. Thus in running projects, organizations act in a tolerance zone which is a performance band in which the firm is satisfying the interests of all its key stakeholder groups (Doyle and Stern 2006). As projects can swing out of this tolerance band, there is a need to monitor their progress continuously.

The orientation of stakeholders' stakes can be cultural or political (Mintzberg 1995). Stakes also have the attributes of legitimacy, power and urgency and these vary in intensity (Carroll and Buchholtz 2006). In this regard,

- legitimacy is the perceived validity of a claim to a stake;
- power is the ability or capacity to produce an effect; while
- urgency is the degree to which a claim demands immediate attention.

Stakes are not static, neither is a stakeholder matrix. Thus, stakes need to be monitored regularly and major changes assessed against the matrix. The dynamic matrix is essentially not an answer to everything; rather it helps to (Vogwell 2002):

- bring order to a very complex situation;
- bring collective understanding if compiled by a group;
- suggest up-to-date strategies for management and communication of the various groups;
- manage resources and time and use these where most benefit will be derived.

Engaging stakeholders

Power differentials between stakeholders dictate measures for dealing with each other. The strategies and tactics for stakeholder management are underpinned on this differential (Kolk and Pinkse 2006). Saliency is the level of claim, attention and priority attached to these attributes and is a feature used in dealing with stakeholders (Mitchell *et al.* 1997; Gago and Antolìn 2004).

Stakeholders can be engaged through a combination of the following:

- consultation;

- dialogue;
- education;
- partnership;
- control;
- giving them information through:
  - charrette;
  - site walks;
  - workbook development.

A summary of the main methods for engaging stakeholders is as follows:

- corporate events, e.g.:
  - conference style events for building awareness;
  - workshops and plenary sessions;
  - cascade briefings;
  - obtaining slots on the agendas of existing meetings;
- exhibitions;
- one-to-one meetings;
- engagement of stakeholders as change agents;
- use of non-verbal communication:
  - posters;
  - leaflets;
  - websites;
  - newsletters/email/circulars.

Benefits of stakeholder management

Managing stakeholder relationships encourages trust, and stimulates collaborative efforts and these lead to relational wealth, i.e. increased organizational assets arising from familiarity and teamwork. Stakeholder management will improve the final outcome of projects and ensure the commitment of stakeholders (Smith and Love 2004). Companies that are stakeholder-inclusive have fared better (Wheeler and Sillanpää 1997).

Stakeholder management can deliver many other benefits and these include (Roome and Wijen 2006):

- increased process and organizational efficiency;
- waste reduction and lower costs;
- stronger market position;
- reduced risk of prosecutions;
- identification of new business opportunities;
- good public and local community image;
- foresight on upcoming issues;

- lower insurance premiums;
- easier access to financial support;
- enhanced organizational learning.

Downsides of stakeholder management
Inadequate management of external stakeholders can yield the following negative consequences (Ismodes 1997; Carroll and Buchholtz 2006):

- conflicts with the local community;
- complicated decision-making processes;
- time delays and associated cost overruns while assessing and responding to claims;
- negative publicity for the companies involved;
- difficulty in prioritizing and responding to stakeholders' claims.

Despite the numerous advantages of stakeholder management which seem to outweigh the downsides the possibility exists for the latter to manifest; and when they do manifest the consequence(s) can be drastic. It is thus feasible to treat the potential downsides as sources of risk. Thus stakeholders must be managed proactively to avoid projects going wayward. A proactive approach will either avoid the downsides or minimize them to the barest minimum.

Corporate existence and activities are conceivable in three domains (Logsdon and Wood 2000):

- governance;
- processes; and
- outcomes.

These three domains have a bearing on stakeholder management. Governance and processes have a direct relationship with the way a firm engages its stakeholders. The achievement of outcomes is then influenced by an organization's stakeholders.

A construction scheme passes through several phases from beginning to end. These have been described in many ways, e.g. conception, briefing, design, contract, physical delivery, occupation and beyond. At each stage of this journey, the stakeholders and their saliency would differ. There is a need thus to coordinate stakes from the beginning to the end of a project. How this coordination is currently done and how it can be improved is part of the issues that were explored in the research described below.

RESEARCH AND ITS METHODOLOGY

A scoping research to evaluate construction stakeholder management was carried out. The research sought to establish the current position of stakeholder management in construction. The aspects investigated included:

- the appreciation of stakeholder management;
- the support for stakeholder management;
- the approaches to stakeholder management;
- the gains and pains of stakeholder management;
- the role of coordination in stakeholder management.

Interviews with key project stakeholders were conducted on these themes from July to December 2006. The interviews were not structured and each was facilitated by an appointment and held at the interviewee's office. Twelve interviews were conducted with high-ranking officers who included directors, senior project managers, senior site managers, an architect and a users' representative. Notes were taken during the interviews; however, circumstances allowed for the audio recording of three of these interviews using an MP3 player.

The interviews were staggered, averaging two per month. This spacing of interviews enhanced the compilation of information and progressive analysis of data, given that not many interviews were recorded. The outcome of the first interview was used as a basis for conducting the second; and that sequence continued with subsequent interviews. Thus the grounded theory methodology (Strauss and Corbin 1990, 1994) underpinned the study. Findings were established and grounded as the interviews progressed. Each interview lasted one hour on average: the shortest taking about 40 minutes, and the longest 70 minutes.

The data generated were mainly verbal and non-numerical. The analysis focused on extracting and corroborating meaning from the data. Content analysis was in this wise utilized.

The opinions and anecdotes of the interviewees were analysed and interpreted to derive themes of meaning. For instance, when some of the interviewees indicated that the website was useful for keeping some external stakeholders informed, it was gathered and corroborated with other interviewees that a detached mode of communication was adequate for engaging stakeholders that have a low level of interest in a project. Content was analysed and interpreted in a similar fashion.

For this article, only one aspect of the information was extracted and analysed, i.e. relating to leadership. It is an issue that surfaced during the first set of interviews and its essence was substantiated in some of the subsequent interviews. This particular aspect of the findings informs this article while the other findings will be disseminated in another forum.

The need for effective leadership in stakeholder management

Although the research examined several issues, this paper concentrates on the aspect of coordination in the course of stakeholder management. This aspect became apparent from the very first interview. The need to coordinate the many stakes in construction was confirmed by the interviewees. Since stakes are very fluid, the level of interest in a need could change at any time. Consider, for instance, a hospital scheme being procured by means of the 'private finance initiative' (PFI); the perception of the neighbouring community concerning this hospital could suddenly change thus:

Initial perception of the scheme	*Later perception of the scheme*
'It is okay, we'll have new facilities'	'We do not like this form of procurement, it is too expensive on the tax payer'

Such a change of opinion could be orchestrated by say, a newspaper article – the media being another stakeholder, notably. Thus, stakes must be identified and their saliency monitored and managed continuously. Someone with authority (a leader) is needed to monitor and manage stakes.

This foregoing scenario is akin to risk management where risks are identified *a priori* and plans put in place upfront for their management. Uncertainty with respect to an outcome is associated with a risk event. At the stage of signing a contract, the project price and duration are usually established. Anything that undermines the completion of the project within the established price or time is a source of risk. The principle of risk management is to identify all the risks associated with any project, assess their potential impacts, mitigate them as much as possible and manage any residual risks that cannot be mitigated (Smith *et al*. 2006). The ideal is to adopt a proactive rather than a reactive approach. That way, no risk will materialize unexpectedly. If all risks associated with a project can be identified upfront and their likely impacts assessed accurately, then any eventuality can either be curtailed or managed appropriately. Likewise, stakeholders have the potential to threaten a project, i.e. they pose a risk. Thus, a proactive approach is needed for managing stakeholders.

Having begun a construction project, the involvement of stakeholders is often unavoidable. Meanwhile each stakeholder poses a certain level of risk to the project which often cannot be transferred or avoided. Stakeholders can delay a project and can even scuttle a scheme. If stakeholders with high power and high interest say this project is not going ahead then it is almost certainly not going ahead, unless they are convinced otherwise. If for instance Her Majesty's Treasury says to a particular National Health Service Trust in the UK, we are not happy with your public sector comparator and are thus unwilling to fund your hospital project then that scheme cannot proceed. If a local authority says to a construction client that the building design does not merit the granting of full planning permission, then that project cannot proceed in its current form. Suffice to indicate that the risks posed by stakeholders are consequential; however, such risks can be eliminated or reduced drastically through stakeholder management. It is possible to optimize the reduction of the risks posed by stakeholders through effective stakeholder management. The interviews in the research suggested that effective stakeholder management is a great contributor to project success and that it is worthwhile for each organization not to undermine the essence of managing stakeholders.

Contemporary construction projects could involve 40 to 75 stakeholder firms and some of these projects are promoted or funded by many establishments. In the UK, regional governments can be found in some key client groups which, is a complexity in itself (Vogwell 2002). When many stakeholders abound, it is not inconceivable for their interests to vary. For instance, one client-stakeholder may be more interested in the durability of building components; another in an iconic building; yet another in a specific location that maximizes the return to them in terms of money invested, etc. The differing aspirations of this cluster of key stakeholders have to be managed; then as they engage with other stakeholders, another dimension of complexity unfolds itself. Thus the dynamics of stakeholder interactions are much more complex than meets the eye. The potential for harbouring slightly different views is quite high. So instead of a project progressing in one direction, the different views of some stakeholders could be pulling it in different directions or slowing down its progress. It is a great risk for the interests of the stakeholders to be misaligned; it is much more complex when cliques of stakeholders emerge. With cliques the power of each sub-group is strengthened. It is thus worthwhile to have a framework for steering the different stakes so that they all move in one direction. A leader to manage this framework is equally important.

Where there are stakeholders with low interest and low power, it may be relatively easy to manage them by keeping them fully informed before, during and after relevant activities in a project. Thus, for instance, if the drainage system of a certain locality is being upgraded, the residents in that area would be informed before the works begin and given a timeframe when the works will be completed. If there are any delays in carrying out such works, the residents will be told and given a revised timetable for completing the project.

Stakeholders with 'low interest and high power' and those with 'high power and low interest' are kept informed regularly as well as consulted occasionally and their views are always considered in decision making. The risk level of these two groups ranges from moderate to high. Nothing should be taken for granted with these stakeholders, i.e. there should be no delay in attending to their needs as an issue that may seem trivial to them can develop into a significant issue easily and suddenly.

Stakeholders with ‘high interest and high power’ have the greatest potential to interfere with a project. Their positions are very important and their different views have to be sorted always in some way, as none of them should be undermined. If several of such high powered stakeholders have conflicting stakes, a means of resolving such tactfully must be sought as you would want to keep all of them on board and happy at the same time. This is where the importance of leadership becomes even more paramount, by addressing the soft skills of vision, working together, motivation, building trust among the players and ethics (Rubin *et al*. 2002). Leadership is about establishing direction, aligning people, and motivating and inspiring others (Kotter 1990).

Cleland (1999) argues that project leadership should befit the project situation because the act of leading is a continuous and flexible process. Indeed, construction projects pass through different phases and so construction professionals need different leadership styles in the different phases of the project life cycle as the stakes are highly dynamic (Bresnen *et al*. 1986). Naum (2001) suggests that leaders may have to switch from one style of leadership to another or combine elements of different styles in order to strike the right balance for each occasion.

Although the diverse leadership styles can be represented on a continuum Giritli and Oraz (2004) have generalized these into two domains: the democratic or participative type and the autocratic or authoritarian type. The leadership that is more useful for stakeholder management is not the full autocratic style but an approach that combines more emphasis on coordinating and less on controlling. It is the leadership attributes of organizing and communicating that are predominant in stakeholder management. According to Naum (2001) large capital investment projects involve making several highly complex decisions and this requires different styles of leadership; however, a participative style of leadership is much more appropriate than a directive style.

When many stakes interact and conflict with each other compromises are needed, and stakeholders may sometimes agree these among themselves. However, a leader can facilitate this agreement to ensure that all the parties involved are fully satisfied. Clear and common goals are also very vital in stakeholder management and part of the role of leadership is to ensure the emergence of common goals that are communicated to all stakeholders. These shared goals then become the basis on which a project should proceed.

Deriving common goals for a project is not necessarily a one-man task. For instance, a workshop can be used to elicit the expectations of stakeholders, and this can even be done anonymously say, by means of the Delphi technique. Participants at the workshop can also be used to map the expectation(s) of the whole set of stakeholders and to steer an optimal course for the project. This approach inadvertently gives the stakeholders more satisfaction, knowing they were part of the decision that carved a way forward towards yielding an optimal outcome. In any case, a leader is still needed to drive such a process through.

Stakeholder management is mostly carried out at a higher level and it is often approached as an inter-organizational affair. Thus the hard issues of construction are not so much under scrutiny here though they are relevant. It is the relational and soft issues that count much in stakeholder management, hence the essence of coordination.

DISCUSSION

Today, most construction clients are configurations of stakeholders (Newcombe 2003). Also, modern construction practice is characterized by large supply chains, with a leading contractor having to manage their supply chain. Effectively, there is a multifaceted client engaging a multifaceted supplier in construction. The stakes involved are thus numerous, varied and fluid. The risk of conflicts arising in such a setting is quite high. The potential for opportunism is also quite high and if everyone is looking after their own interests only, who will look after the interest of the whole? It is not a case of ‘gather the pennies and the pounds will gather themselves’. It is thus worthwhile for leadership to emerge where stakeholders abound, and the broad view of this leadership should focus on keeping the project objectives on track while balancing the achievement of each stake.

When an organization focuses on one stakeholder alone, the interests of the other stakeholders are devalued (Doyle and Stern, 2006). A fundamental responsibility of a firm therefore is to reconcile the diverging and conflicting interests of its stakeholders. Modern construction stakeholder management must be developed specifically to address any peculiarities in this sector. As a start, stakeholder management must be developed as a key competence, and this must be reflected in training curricula.

Construction clients have underperformed in terms of providing effective leadership (Latham 1994) and setting clear needs or goals (Boyd and Chinyio 2006). This has contributed in projects with less than optimal outcomes. Stakeholder management as a mutual quest can plug this gap.

Stakeholder management must be resourced and organizations may not have enough time and resources to attend to all stakeholders. The mapping of stakeholders and prioritization of the usage of resources is thus essential. A relatively lax approach can be adopted for dealing with stakeholders with very little interest while a hands-full approach is used for those with greater interest. In this regard, stakeholders with minimal interest in a project are kept informed via newsletters, websites and the like.

Since clients initiate projects, it may be worthwhile for them to steer the project’s course initially before different stakeholders come on board. The need for more effective client leadership is thus reiterated here. In the course of developing a project different stakes will emerge along the line, some with very high potency. Thus as a project unfolds, a think-tank that will coordinate the different stakes may be essential, else the risk of alienating one or more stakeholders becomes high. The think-tank can provide leadership that will harmonize the different stakes and help steer the project with minimal interruptions. It may be that this think-tank is composed of some of the stakeholders or independent experts or a combination of both.

Leadership has been studied for many centuries and can be traced to writings from the philosopher Epictetus in the first century AD (Butler and Chinowsky 2006). There are many aspects of leadership, and there is no consensus among researchers as to the definition of leadership; however, Butler and Chinowsky (2006) identified interpersonal skills and empathy as important aspects of leadership and suggested that construction industry executives should pay additional attention to these. Literature seems to suggest that soft issues are very important in leadership and the scoping study discussed in this paper has identified leadership as an important aspect of construction stakeholder management.

The research discussed in this paper involved 12 interviews; and it established the complexity of stakeholder management as well as the need for further studies into this subject matter. The interactions between construction stakeholders are very fluid and highly complex. The scoping study could not capture all the dynamics therein hence there are plans to investigate further into construction stakeholder management. An enlarged study is being designed with the aim of establishing theory in this domain. The findings of the scoping study are informing this subsequent research where leadership will be a key feature.

Although several findings were established in the scoping study, this article has discussed the aspect of leadership only. The other findings which concern strategies and tactics for stakeholder management are being synthesized for dissemination through another medium.

CONCLUSION

Several stakeholders are associated with most modern construction projects and the potential for their respective stakes to conflict with each other could be very high. Stakes are also very fluid. This warrants a coordination of the dynamic stakes and controlling their progress to avoid their adverse consequences. In this regard, effective leadership is very vital for stakeholder management; for it will provide a set of common goals for the stakeholders and coordinate their diverse aspirations towards these common goals. This is not an autocratic form of leadership but a stewarding of stakes towards maximizing overall value in a project. It is a form of leadership that emphasizes coordination and listens to what the stakeholders want and helps to steer them towards achieving the common goals of the project. A think-tank may be needed to provide this sort of leadership. Meanwhile, a follow-on research is being planned to partly study the skills needed for providing leadership among stakeholders.

REFERENCES

Boyd, D and Chinyio, E (2006) *Understanding the construction client.* London: Blackwell Publishers.

Bresnen, M J, Bryman, A E, Ford, J R, Beardsworth, A D and Keil, E T (1986) The leader orientation of construction site managers. *ASCE Journal of Construction Engineering and Management*, **112**, 370–86.

Butler, C J and Chinowsky, P S (2006) Emotional intelligence and leadership behavior in construction executives. *Journal of Management in Engineering*, **22**(3), 119–25.

Calvert, S (1995) *Managing stakeholders: the commercial project manager*. New York: McGraw-Hill.

Carroll, A B and Buchholtz, A K (2006) *Business & society: ethics and stakeholder management*. 6ed. Mason, OH: Thomson South-Western.

Cleland, D I (1999) *Project management – strategic design and implementation*. 3ed. New York: McGraw-Hill.

Donaldson, T (2002) The stakeholder revolution and the Clarkson principles. *Business Ethics Quarterly*, **12**(2), 107–11.

Doyle, P and Stern, P (2006) *Marketing management and strategy*. 4ed. Harlow, Essex: Pearson Education Limited.

Freeman, R (1984) *Strategic management – a stakeholder approach*. Boston, MA: Pittman Publishing Company.

Freeman, R E (1994) A stakeholder theory of the modern corporation. *In*: T L Beauchamp and N E Bowie (Eds.) *Ethical theory and business*. Englewood Cliffs, NJ: Prentice-Hall.

Frooman, J (1999) Stakeholder influence strategies. *Academy of Management Review*, **24**(2), 191–205.

Gago, R F and Antolìn, M N (2004) Stakeholder salience in corporate environmental strategy. *Corporate Governance*, **4**(3), 65–76.

Giritli, H and Oraz, G T (2004) Leadership styles: some evidence from the Turkish construction industry. *Construction Management and Economics*, **22**(3), 253–62.

Goodpaster, K E (1991) Business ethics and stakeholder analysis. *Business Ethics Quarterly*, **1**(1), 53–73.

Ismodes, A (1997) *Socio-economic aspects in water resources development*. Stockholm: Avdelningen för Vattenbyggnad, Kungliga Tekniska Högskolan.

Kolk, A and Pinkse, J (2006) Stakeholder mismanagement and corporate social responsibility crises. *European Management Journal*, **24**(1), 59–72.

Kotter, J P (1990) *A force for change: how leadership differs from management*. New York: Free Press.

Logsdon, J M and Wood, D J (2000) Introduction. *In*: J M Logsdon, D J Wood and L E Benson (Eds.) *Research in stakeholder theory, 1997–1998: The Sloan Foundation Minigrant Project*. Totonto: Clarkson Centre for Business Ethics.

Mitchell, R K, Agle, B R and Wood, D J (1997) Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. *Academy of Management Review*, **22**(4), 853–86.

Naum, S (2001) *People & organizational management in construction*. London: Thomas Telford.

Newcombe, R (2003) From client to project stakeholders: a stakeholder mapping approach. *Construction Management and Economics*, **21**(8), 841–8.

Orndoff, C J W (2005) Promising new tool for stakeholder interaction. *Journal of Architectural Engineering*, **11**(4), 139–46.

Roome, N and Wijen, F (2006) Stakeholder power and organizational learning in corporate environmental management. *Organization Studies*, **27**(2), 235–63.

Rubin, D K, Powers, M B, Tulacz, G, Winston, S and Krizan, W G (2002) Leaders come in all shapes and sizes, but the great ones focus on people. *Engineering News-Record*, **249**(23), 34–6.

Smith, J and Love, P E D (2004) Stakeholder management during project inception: strategic needs analysis. *Journal of Architectural Engineering*, **10**(1), 22–33.

Smith, N J, Merna, T and Jobling, P (2006) *Managing risk in construction projects*. 2ed. Oxford: Blackwell.

Strauss, A and Corbin, J (1990) *Basics of qualitative research*. Newbury Park, CA: Sage.

Strauss, A and Corbin, J (1994) Grounded theory methodology: an overview. *In*: N K Denzin and Y S Lincoln (Eds.) *Handbook of qualitative research*. Thousand Oaks, CA: Sage.

Vogwell, D (2002) *How risky are your stakeholders?*, Report for Davis Langdon and Everest, available at http://www.eurolog.co.uk/apmrisksig/meetings/stakeholders.pdf (accessed 21 June 2006).

Weiss, J W (2006) *Business ethics: a stakeholder and issues management approach*. 4ed. Mason, OH: Thomson Higher Education.

Wheeler, D and Sillanpää, M (1997) *The stakeholder corporation: a blueprint for maximizing stakeholder value*. London: Pitman Publishing.

Winch, G and Bonke, S (2002) Project stakeholder mapping: analysing the interests of project stakeholders. *In*: D P Slevin, D I Cleland and J K Pinto (Eds.) *The frontiers of project management research*. Pennsylvania: Project Management Institute (PMI).

ECONOMIC CONSIDERATIONS IN OUTSOURCING OPERATION AND MAINTENANCE SERVICE FOR COMMERCIAL BUILDINGS

Joseph Lai[1] and Francis Wai Hung Yik

Department of Building Services Engineering, The Hong Kong Polytechnic University, Yuk Choi Road, Hunghom, Kowloon, Hong Kong

The overblown property market in Hong Kong burst during the Asian financial crisis in 1997. After a lengthy slump, the property prices are yet to revert to their peak levels. To reduce expenditure while striving for better income, owners have increasingly outsourced operation and maintenance (O&M) services for their buildings. Whether the outsourcing is really economical hinges not only on the cost saving, but also on the change in building value, which is dependent on the performance of the contract service. Through a series of face-to-face interviews with 22 experienced practitioners playing the roles of owner, property management and O&M contractor for commercial buildings, the study examined the perceived importance of the attributes contributory to an efficient contract. Despite the difficulty of measuring transaction costs, a pragmatic model developed via analysing the opinions of the practitioners is submitted for gauging the *ex ante* and *ex post* costs variation.

Keywords: commercial property, maintenance, outsourcing, transaction cost.

INTRODUCTION

Hong Kong is the eleventh largest trading economy in the world and the second biggest stock market in Asia (HKSAR 2005). Sustainable economic development, which is central to the society, relies on having quality commercial buildings which accommodate business activities. Many of these buildings, equipped with sophisticated engineering services such as central air-conditioning, intelligent controls and IT facilities, were built in parallel to the growing economy in the past few decades. Without proper operation and maintenance (O&M), however, the value of these built assets will be undermined and the business activities affected.

Derived from statistical data (RVD 2004, 2006), the rental and price indices (100 in year 1999) of office and retail premises dropped drastically from the peak in 1997 to a trough in 2003 when the Severe Acute Respiratory Syndrome (SARS) outbreak further ruined the already weak economy (Figure 1). According to JLL (2004a, 2004b), the office vacancy rate had been significant and the anticipated negative demand of office space in Hong Kong ranked first among the major Asia Pacific cities.

Following China's entry into the World Trade Organization (WTO), Hong Kong and the Mainland China jointly signed a Closer Economic Partnership Arrangement (CEPA) in 2004 to strengthen trade and investment cooperation between the two sides

[1] bejlai@polyu.edu.hk

(HKSAR 2005). In particular, Article 13 of CEPA states the measures for further strengthening cooperation in the areas of banking, securities and insurance. Article 14, which deals with cooperation in tourism, provides that the Mainland will allow residents in Guangdong Province to visit Hong Kong individually in order to further promote the development of the tourism industry in Hong Kong (TID 2003).

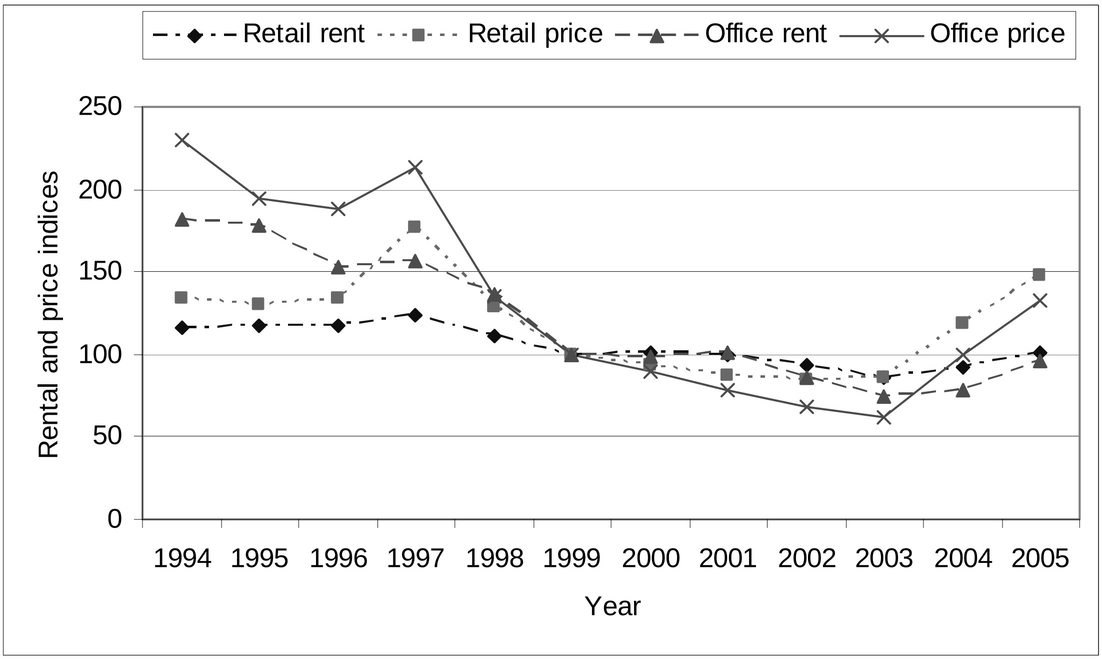


Figure 1: Rental and price indices (100 in year 1999) of commercial premises

Anticipating larger demand of commercial premises from organizations which would establish or expand their businesses to match the implementation of the CEPA, the property market started to recover (Figure 1). Notwithstanding that the Hang Seng Index also climbed to a record high of 20 001 at the end of 2006 (HSI 2007), the rental and price indices are yet to revert to their peak levels in 1997. (The Hang Seng Index, which is a compilation index of the leading stocks in the Hong Kong stock market, is the main indicator of the overall market performance.) As a corollary, owners have been unable or reluctant to invest in O&M work despite their desire to improve its quality to attract higher building income. Data compiled from RVD (2004, 2006) further reveal that the amount of new buildings has perpetually outweighed that of the demolished, giving a continuous rise in building stock (Figure 2). Confronted with these challenges, many building owners resorted to outsourcing (Yik and Lai 2005).

The number of large public and private organizations which outsourced O&M work for their buildings has been increasing, but there were cases where the work was brought back to in-house production (HKET 2005). This suggests that outsourcing may not always be beneficial, as forming and managing contracts necessitate transaction costs (Williamson 1979) and the quality of the procured service may not meet the outsourcer's expectation. Regardless of the overwhelming reports on outsourcing incidents as compared to those on in-sourcing, whether they brought along genuine benefits and more fundamentally, whether the outsourcing decisions were given rational consideration seem to be unknown.

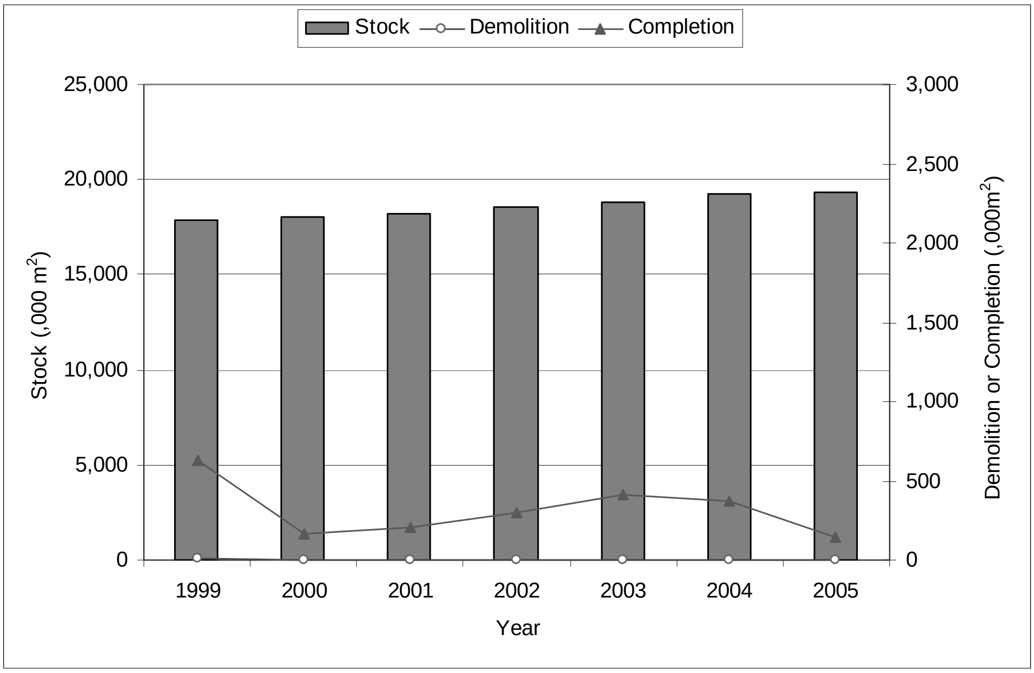


Figure 2: Commercial building stock, demolition and completion

An earlier study (Lai *et al*. 2004) found that building owners typically engage an in-house team to be responsible for some minor O&M work which is routine (e.g. daily patrol, manual logging of instrumentation readings) or which requires prompt remedial actions (e.g. burst pipe, circuit trip). Works that necessitate execution by licensed contractors (Lai and Yik 2004) or the workload of which is large but fluctuating are commonly procured through an intermediate property management company. Each of these stakeholders plays a vital role in ensuring proper delivery of the work. Their views on what attributes are critical to an efficient contract and the significance of various cost elements are essential considerations before going for outsourcing.

THE INTERVIEWS AND SAMPLES

A questionnaire was designed to collect information and opinions from O&M practitioners working on commercial buildings. The first part of the questionnaire inquired into their personal information including age, job nature and years of work experience; and the type, nature and contractual arrangement of an O&M contract work they consider representative. The second part solicited the respondents' perceived importance of a list of attributes which contribute to an efficient contract. These attributes, classified as 'economic attributes', are factors affecting the price level and thus the efficiency of the O&M contract. Subsequent to each question in this part, the respondents were asked to openly express the reasons for their response. Finally, they were asked to draw on their experience to indicate the significance of the contract sum, in-house cost and its elements including labour, material and overheads associated with the delivery of O&M work. Their comments on what major factors influence the significance of these cost items were also sought. Although for the purpose of accurate cost analysis it is more preferable to obtain the exact figures of the costs, it was only feasible to collect indications about their significance because of the following:

- Different organizations classified O&M costs into different categories, thus the cost data collected were not useful for analysis.
- The record of O&M costs was not in all cases kept in proper order.
- The interviewees refused to provide cost figures which are sensitive or confidential.

Before conducting the interviews in full swing, three pilot interviews were conducted. The comments so gathered, including those suggested to modify, add or delete some of the attributes, were taken to refine the questionnaire. For ensuring proper interpretation of the meaning of the attributes by the interviewees, the survey was carried out by way of individual face-to-face interviews during which the same interviewer explained the questions and clarified any queries before the interviewees gave their answers. Although this survey method entailed significant resources for making appointments with the interviewees and for travelling to and from their workplaces one at a time, it helped obtain quality data (Fowler 2002).

Interviewees were invited at random from members of the Building Services Operation and Maintenance Executives Society (BSOMES) and proficient practitioners with whom the project investigators had contacts. Twenty-two interviews were successfully completed where all the participants are experienced practitioners, with over 13 years of experience on average. The majority group comprises 12 practitioners working for property management companies, another six are employed directly by building owners to look after the O&M work for their buildings, and the rest are employees of O&M contractors hired by building owners or property management companies. Despite the relatively small sample size of the owner group, they are the volunteers who can provide reliable empirical information.

ECONOMIC ATTRIBUTES CONTRIBUTING TO AN EFFICIENT CONTRACT

The interviewees were asked to express their perceived importance of the economic attributes (A_E) using a five-point cardinal scale (r_i = 1 for ‘not important’ to 5 for ‘very important’). The average ratings $R(A_E)$, as shown in Table 1, were calculated by using Equation 1 where i is the contract number (1, 2, 3, …, N) and N is the total number of sampled contracts.

$$R(A_E) = \frac{\sum_{i=1}^{N} r_i}{N} \quad (1)$$

The interviewees considered ‘suitable contract pricing structure’ and ‘suitable tendering method’ as the most important economic attributes (both with $R(A_E)$ = 4.00), even though their comprehension of the various contract concepts and contract formation methods were less than satisfactory (Lai *et al*. 2006). A similarly high importance rating was given on the attribute ‘good financial status of the contractor’ ($R(A_E)$ = 3.95), which suggests the need for the contractor to finance the work upfront when there are time lags or delays in contract payment.

Table 1: Perceived importance of economic attributes

Economic attributes	**Overall**	**Owner**		**Property management**		**Contractor**	
	$R(A_E)$	$R_O(A_E)$	Rank	$R_P(A_E)$	Rank	$R_C(A_E)$	Rank

Suitable contract pricing structure	4.00	4.17	4.5 (3.5)	3.67	3 (3)	4.75	— (1)
Suitable tendering method	4.00	4.33	1.5 (1)	3.67	3 (3)	4.50	— (2.5)
Good financial status of the contractor	3.95	3.83	8 (7)	3.92	1 (1)	4.25	— (4)
Optimum length of contract period	3.77	3.83	8 (7)	3.50	5.5 (5.5)	4.50	— (2.5)
Low labour cost in market	3.68	3.67	10 (9)	3.67	3 (3)	3.75	— (7.5)
Cost saving compared to in-house production	3.61	4.33	1.5 (NI)	3.25	7 (NI)	NA	— (NI)
Good global economic environment	3.59	4.17	4.5 (3.5)	3.17	8 (7)	4.00	— (5.5)
Large contract sum	3.50	4.17	4.5 (3.5)	3.00	10.5 (9.5)	4.00	— (5.5)
Low material cost in market	3.41	3.83	8 (7)	3.08	9 (8)	3.75	— (7.5)
Amble budget allowed	3.27	3.50	11 (10)	3.50	5.5 (5.5)	2.25	— (11)
Regular budget reviews	3.27	4.17	4.5 (3.5)	3.00	10.5 (9.5)	2.75	— (10)
Large contingency allowed	2.91	2.50	12 (11)	2.92	12 (11)	3.50	— (9)

Notes:
NA: Not applicable to the contractors.
NI: Not included in the calculation of Kendall coefficient of concordance.
Figures in parentheses represent the ranks when the inapplicable attribute (marked as NA) is omitted.

Among the lower tier of attributes, ‘optimum length of contract period’ was rated as highly important ($R(A_E)$ = 3.77). A very short contract period means the transaction costs for forming recurrent contracts would be incurred frequently and the trust that can be built between the contracting parties would be weak. If the contract period is overlong, unless relevant contract provisions have been allowed the locked-in employer would find it hard or costly to adjust the service level to meet any change in the needed O&M standard. Dealing with a contractor with low incentive to provide quality service, especially at a later stage of the contract period, the employer would need to choose between inputting more effort to monitor her performance and tolerating the unsatisfactory service.

The attributes that the interviewees perceived as comparably less important include: ‘low labour and material costs’, ‘good global economic environment’ and ‘large contract sum’ ($R(A_E)$ = 3.41 to 3.68). Obviously, when the contractor can hire labourers with lower wages and purchase materials at lower costs, the employer would be more likely to receive the service on time, meeting the required quality. A better economic environment would also mean the contractors would have more market opportunities. With better job security and prospects, the contractor staff would be more devoted to their work to provide higher service quality. Meanwhile, building owners who are less pressured to cut O&M budgets would be able to procure quality service from competent contractors. For contracts with large contract sums, the contractor would be more able to maximize his profit by virtue of economies of scale and the employer would need to spend, in relative terms, less resources to monitor the contractor performance (Lai and Yik 2007a).

While the building owners rated cost saving obtainable through outsourcing as highly important ($R_O(A_E)$ = 4.33), the property management personnel only rated its importance as fair ($R_P(A_E)$ = 3.25). This is because the latter is a managing agent whose remuneration, unless provided for in the contract, is independent of the amount of money that the owners can save. To the contractors, this attribute is irrelevant given that none of the sampled contracts had incorporated any 'shared saving' conditions.

O&M stakeholders should feel much relaxed when there is an ample budget. However, this attribute only recorded a relatively low importance rating ($R(A_E)$ = 3.27). This may be attributed to the variable and loose practices of O&M budgeting (Lai and Yik 2007b). The same explains why 'regular budget reviews' carried an identical importance rating. Finally, because contingency was seldom allowed in O&M contracts to cater for unforeseen scenarios (Lai *et al*. 2006), 'large contingency allowed' was rated as the least important ($R(A_E)$ = 2.91). The different view of the contractors on this attribute ($R_C(A_E)$ = 3.50) suggests that they are often forced to shoulder contractual responsibilities which are vaguely defined (Lai *et al*. 2004) and additional works which lie in the loopholes of contract (Lai *et al*. 2006), while hoping that the contingency sum, if provided in the contract, could disburse these works.

Equation 2 is used to calculate the Kendall coefficient of concordance (W) so as to test the relative agreement of the perceived importance ratings (Kendall and Gibbons 1990) among the different groups of practitioners. The sum of the squares of the deviations (S) of the row rank sums (R_i) from their mean value $m(n+1)/2$ pertaining to the n attributes rated by the three groups (i.e. m = 3) is determined by Equation 3, where u_j is the number of consecutive members of the j^{th} tied rank. A moderate level of agreement (W = 0.608) was found among the groups.

$$W = \frac{12S}{m^2(n^3-n) - m\sum_j (u_j{}^3 - u_j)} \tag{2}$$

$$S = \sum_{i=1}^{n}\left[R_i - \frac{m(n+1)}{2}\right]^2 \tag{3}$$

$$S_r = 1 - \frac{6\sum_{c=1}^{N} d_c{}^2}{N^3 - N} \tag{4}$$

Spearman rank correlation coefficient (S_r) was further calculated (Equation 4) in order to examine the consistency of the perceived importance ratings between pairs of the three groups. The correlation between the owner group and the property management group was found to be insignificant (S_r = 0.110), reflecting their different views on the attributes. On the other hand, the correlation between the property management group and the contractor group (S_r = 0.566) and that between the owner and contractor groups (S_r = 0.700) are significant. Note, however, must be taken that they were calculated on a basis which is slightly different from that between the owner group and the property management group because the attribute 'cost saving compared to in-house production', which is inapplicable to the contractors, was excluded from the calculations.

A PRAGMATIC TRANSACTION COST MODEL

The foregoing results show that different groups of O&M practitioners have different perceptions of the attributes, which is not surprising given their differences in job natures, roles and interests. In particular, the importance of the attributes perceived by the owner and property management parties would have profound influence on their consideration in outsourcing. But the fact that these perceptions are drawn from subjective judgment of some intrinsically qualitative issues often attracts criticisms on an outsourcing decision made on such basis. A decision buttressed with quantitative justification, for instance, in terms of costs, is definitely more convincing. According to the interviewees, however, a cost model which can really help them make this kind of decision is missing, with which the result of a literature review of the current study also agrees.

In principle, whether to go for outsourcing depends not only on how much can be saved, but also on how much the ensuing building value would vary. If the building value is impaired owing to a lowered quality of the contract service, the cost for ameliorating the quality may outweigh that saved from outsourcing. Even if value is added to the building, it should be evaluated against the transaction costs that the contract incurs, as outsourcing is really economical only when there is a net gain in benefit.

The evaluation, however, is not practically simple. First, although any change in the value of the building may be determined by referring to its price or rental level, it is not solely dependent on the change in O&M service quality. Other factors, for instance, market supply and demand of the same type of building premises, may also affect the building value. Second, quantifying the benefits and impacts, some of which are non-monetary and intangible, would involve making assumptions which are arguable. Even when only the monetary cost items are considered, omission of hidden costs and inclusion of sunk costs can often lead to a false evaluation (IC 1996; Eschenbach 2003).

While it is possible to identify the costs for producing O&M work in-house before outsourcing, determining the costs for the same work carried out by contractors would not be possible until the completion of its procurement. But when considering an outsourcing decision, one can pragmatically compare the costs before and after outsourcing using the following model, which is developed through analysing the opinions gathered from the interviews.

Consider a case of total outsourcing where the O&M work is wholly undertaken by a service provider. The outsourcing decision is just if the total O&M cost after the work is outsourced is less than that before, as represented by Equation 5. IC_b is the in-house cost before outsourcing. *OC* denotes the contract sum for the outsourced work, whose magnitude largely depends on the top two attributes – suitable contract pricing structure and suitable tendering method (Table 1). *TC*, which is the transaction cost incurred for forming and managing the contract, is also an essential component in the evaluation.

Instead of total outsourcing, partial outsourcing prevails in practice (Lai *et al*. 2004) where IC_a is the resource needed to execute the portion of work retained in-house (Equation 6). *OC* can be readily obtained from the accepted tender price, but IC_a and part of TC (i.e. *ex post* transaction cost, TC_2, as will be explained later in Equation 12) can only be realized some time after the outsourcing. This is represented by Equation 7 where d is the discount rate and t is the time difference between evaluating the costs before and after outsourcing.

$$TC + OC < IC_b \quad (5)$$

$$IC_a + TC + OC < IC_b \quad (6)$$

$$\frac{IC_a + TC}{(1+d)^t} + OC < IC_b \quad (7)$$

$$IC_x = \sum_{i=1}^{N} C_{ix} \quad (8)$$

$$\frac{TC}{(1+d)^t} + OC < \sum_{i=1}^{Q} C_{ib} - \sum_{i=1}^{P} \frac{C_{ia}}{(1+d)^t} \quad (9)$$

$$\frac{TC}{(1+d)^t} + OC < \Delta C_{1,b-a} + \Delta C_{2,b-a} + \sum_{i=3}^{Q} C_{ib} - \sum_{i=3}^{P} \frac{C_{ia}}{(1+d)^t} \quad (10)$$

$$\Delta C_{1,b-a} = \left[\sum_{j=1}^{4} N_j \times S_j \times FTE_j\right]_b - \left[\sum_{j=1}^{4} N_j \times S_j \times FTE_j\right]_a + \sum_{d=1}^{D} SP_d \quad (11)$$

Summing the costs of labour, material and overhead gives the total in-house cost for performing the O&M work (Equation 8), where x is a (after outsourcing) or b (before outsourcing), and C_i represents the *i*th in-house cost element with i being '1' for labour, '2' for material and '3 to N' for overheads. Rearranging Equations 7 and 8 gives Equation 9, and then Equation 10 where $\Delta C_{1,b-a}$ and $\Delta C_{2,b-a}$ are the changes in the costs of direct labour and direct material respectively measured before and after outsourcing.

Distinct from new construction project, labour resources involved in minor maintenance work (e.g. routine inspection, cleaning and lubrication, etc.) typically overwhelm the cost of materials used. Change in direct labour cost can be determined based on Equation 11 where N_j is number, S_j is salary, FTE_j is full-time equivalent of in-house O&M staff at different levels (j; j = 1: top management, 2: managerial, 3: supervisory and 4: operational) engaged in the work; and SP_d denotes the severance payment given to the in-house staff (total number D) laid off as a result of the outsourcing. Unlike the protections under the Transfer of Undertakings (Protection of Employment) Regulations in the UK (Jeffers 1996), the Labour Ordinance provides that severance payment is calculated as two-thirds of the last month's wages multiplied by the reckonable years of service of the employee (LD 2007). Whereas changes in headcounts would also lead to variations in cost for covering their fringe benefits such as insurance, medical benefits and other allowances, they can be neglected in the evaluation in view of their relatively small amount.

As for major maintenance work which often is material-demanding while the manpower involved is relatively small, e.g. replacement of a variable speed drive costing HK$50 000 necessitates paying HK$2000 (i.e. 4%) for two technicians supervised by one engineer to complete the work in one hour, any change in direct material cost ($\Delta C_{2,b-a}$) would be significant.

O&M costs are generally regarded as overheads, i.e. indirect costs associated with some core activities of a business. To organizations whose core business is O&M work, on the contrary, O&M costs are direct costs whereas the costs that the supportive works incur are indirect. The number of overhead cost elements before (Q) and after (P) outsourcing depends on the way in which they are categorized. Exact identification of monetary overhead costs, whose classifications may vary from one organization to another, is not easy. Non-monetary overheads, for example, the time needed to accomplish some administrative tasks, is even difficult to measure. Space cost dominates the expenditure of business organizations (Davies 2000). But unless the outsourcing gives rise to dramatic organizational reform and hence downsizing, saving in space cost would not be large and so is the reduction in associated utilities, insurance and maintenance costs. Since condition-based maintenance which makes use of precious monitoring devices remains uncommon in the building sector (Pearson 2002), tools used for daily O&M work, e.g. drills, hammers, etc. are generally inexpensive. Cash infused from disposal of these tools through outsourcing, therefore, would not be enormous.

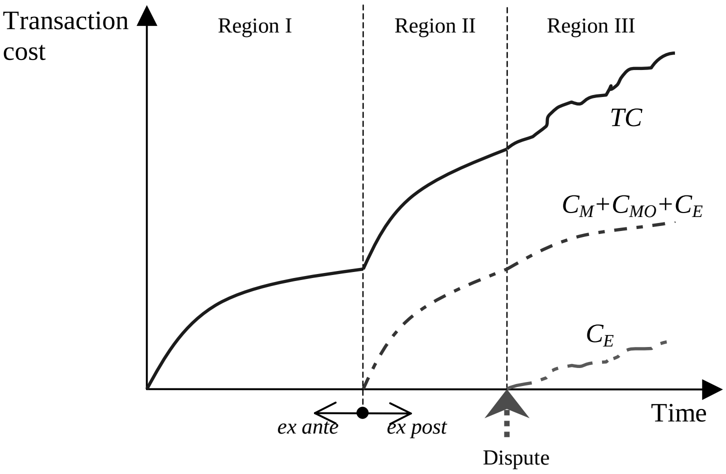


Figure 3: Transaction cost elements on a contract timeline

$$TC = \begin{cases} TC_1 = C_S + C_D + C_N \quad \text{(Region I)} \\ TC_1 + TC_2 = TC_1 + C_M + C_{MO} \quad \text{(Region II)} \\ TC_1 + TC_2 = TC_1 + C_M + C_{MO} + C_E \quad \text{(Region III)} \end{cases} \tag{12}$$

To complete the evaluation in Equation 10, one would need to further comprehend the transaction cost which includes the *ex ante* and *ex post* components. The *ex ante* resources (TC_1) associated with an O&M contract include those deployed to search information (C_S) for drafting the contract document (C_D), and to negotiate with tenderers (C_N) before contract award. The *ex post* transaction costs (TC_2) embrace those entailed in monitoring the contractor performance (C_{MO}), to measure the work done (C_M), and to enforce the contract in case of dispute (C_E). Figure 3 depicts the disposition of these cost elements along a timeline where there is dispute during the contract. Equation 12 represents the total transaction cost (TC) in different regions of the contract timeline. It has been demonstrated how the cost for monitoring O&M contracts can be measured (Lai and Yik 2007a), but the feasibility of measuring the other elements remains to be explored.

CONCLUSIONS

There are variations in the perceived importance of the economic attributes among the different groups of O&M practitioners, but they on the whole considered suitable contract pricing structure and a suitable tendering method as highly important to an efficient contract. Providing a large enough contingency sum in contract was perceived as the least important. This contradicts the theory of incomplete contracting (Hart and Moore 1988) and the reality that unpredictable scenarios always exist in real-life contracts. Further work, therefore, is needed to study what are the crucial factors that give rise to this perception and to focus on contracts incorporated that include a contingency sum to investigate the importance of such provision.

Outsourcing may help cut the O&M costs for buildings but it incurs transaction costs. The difficulty of their precise measurement has been well realized in many empirical attempts (Shelanski and Klein 1995; Masten 1996). It was neither the intention nor the capability of this study to measure the transaction costs associated with building O&M contracts. But a pragmatic model has been developed for gauging the *ex ante* and *ex post* costs variation. When more findings akin to those of Lai and Yik (2007a) are available, decision makers would become better equipped to consider whether to outsource.

REFERENCES

Davies, H (2000) Occupancy costs in Hong Kong. *In*: *Proceedings of the Brisbane 2000 CIBW70 International Symposium on Facilities Management and Maintenance*, 15–17 November 2000, 203–9.

Eschenbach, T G (2003) *Engineering economy: applying theory to practice*. Oxford University Press.

Fowler, F J (2002) *Survey research methods*. Sage Publications.

Hart, O and Moore, J (1988) Incomplete contracts and renegotiation. *Econometrica*, **56**(4), 755–85.

HKET (2005) *News No. A37* (in Chinese). *Hong Kong Economic Times*, 2 September 2005.

HKSAR (2005) *Hong Kong in brief*. Hong Kong Special Administrative Region. Available at: www.info.gov.hk/info/hkbrief/eng/ahk.htm.

HSI (2007) *Hang Seng indexes monthly*, January 2007. Available at www.hsi.com.hk/.

IC (1996) *Competitive tendering and contracting by public sector agencies*, Report No. 48, Industry Commission. Melbourne: AGPS.

Jeffers, R (1996) Outsourcing and TUPE: problems and solutions. *Facilities*, **14**(7/8), 52–6.

JLL (2004a) *Asia Pacific property digest*, *third quarter 2004*. Jones Lang LaSalle.

JLL (2004b) *Asia Pacific corporate real estate impact survey: turning the corner*. 3ed. Jones Lang LaSalle.

Kendall, M and Gibbons, J D (1990) *Rank correlation methods*. Oxford University Press.

Lai, J H K and Yik, F W H (2004) Law and building services maintenance in Hong Kong. *Transactions*, *The Hong Kong Institution of Engineers*, **11**(1), 7–14.

Lai, J H K and Yik, F W H (2007a) Monitoring building operation and maintenance contracts. *Facilities* (forthcoming).

Lai, J H K and Yik, F W H (2007b) A survey of operation and maintenance budgetary practices for commercial buildings in Hong Kong – preliminary findings. *In*: *Proceedings of the World Building Congress*, 14–18 May 2007, Cape Town, South Africa (forthcoming).

Lai, J H K, Yik, F W H and Jones, P (2004) Practices and performance of outsourced operation and maintenance in commercial buildings. *In*: *Proceedings of the CIBW70 2004 Hong Kong International Symposium: Facilities Management & Maintenance*, December 2004, Hong Kong SAR, 357–67.

Lai, J H K, Yik, F W H and Jones, P (2004) Disputes arising from vaguely defined contractual responsibilities in building services maintenance contracts. *Facilities*, **22**(1/2), 44–52.

Lai, J H K, Yik, F W H and Jones, P (2006) Critical contractual issues of outsourced operation and maintenance service for commercial buildings. *International Journal of Service Industry Management*, **17**(4), 320–43.

LD (2007) *A concise guide to the employment ordinance*. Hong Kong: Labour Department. Available at www.labour.gov.hk/eng/public/ConciseGuide.htm.

Masten, S E (1996) Empirical research in transaction cost economics: challenges, progress, directions. *In*: J Groenewegen (Ed.) *Transaction cost economics and beyond*. Kluwer Academic Publishers.

Pearson, C (2002) Condition based maintenance in building services. *Maintenance & Asset Management*, **17**(2), 5–10.

RVD (2004) *Hong Kong property review 2004*. HKSAR: Rating and Valuation Department.

RVD (2006) *Hong Kong property review 2006*. HKSAR: Rating and Valuation Department.

Shelanski, H A and Klein, P G (1995) Empirical research in transaction cost economics: a review and assessment. *Journal of Law, Economics, & Organization*, **11**(2), 335–61.

TID (2003) *Mainland and Hong Kong closer economic partnership arrangement*. HKSAR: Trade and Industry Department. Available at www.tid.gov.hk/english/cepa/legaltext/fulltext.html.

Williamson, O E (1979) Transaction cost economics: the governance of contractual relations. *Journal of Law & Economics*, **22**(October), 233–61.

Yik, F W H and Lai, J H K (2005) The trend of outsourcing for building services operation and maintenance in Hong Kong. *Facilities*, **23**(1/2), 63–72.

A PROPOSED APPLICATION OF USING LCCA TO MEASURE COST OF SUSTAINABLE DESIGN

Wai Kiong Chong,[1] Sanat Kumar Pokharel and Cassandra Leyden

University of Kansas, Department of Civil, Environmental and Architectural Engineering, Learned Hall, 1530 W. 15th Street, Lawrence, KS 66045, USA

Economic decisions far outweigh environmental and social decisions by profit-oriented construction industry where decisions are usually made to maximize both long and short-term profits. Beheiry *et al.* (2006) had clearly stated that market forces are the best tools to advocate sustainability. The success of sustainability implementation depends heavily on the ability to measure and estimate environmental, societal and long-term economic variables, and convert them into benefits and costs. Most industrial practitioners are convinced that sustainability is important but the lack of convincing data and calculations methods hampered the application of sustainability application during the decision-making stage. It is also difficult to convince investors that increasing initial expenditure could benefit them in the long run. Life Cycle Cost Analysis (LCCA) is one of the best tools available to assess the benefit and cost of the construction. This paper reviews different LCCA methods that could measure economic, environmental and social costs of sustainable design and proposes future directions for designer's decision-making process and how LCCA could better be used to convince investors.

Keywords: sustainability, design, life cycle, cost.

INTRODUCTION

The historical tendency to focus on environmental sustainability has over-aligned sustainable development (SD) with the green movement and alienated the business executives (Beheiry *et al*. 2006). Over-aligning SD with green agendas has also prompted a natural gravitation for research to deviate away from business case for sustainability. Beheiry *et al*. (2006) examined the business impact of owner's commitment to sustainability and suggested that balancing between different sustainability strategies may yield higher return on project performance. According to Carassus (2004), fulfilling the requirements of SD would also mean mastering the ability to control the consequences of whole life cycle. Sustainability could also smooth the impact of changes on the economy. Economic analysis has to take into account recent industrial evolution and involves all stakeholders at all stages of project life cycle.

Since cost drives most business decisions, both tangible and intangible benefits are often expressed in economic terms. Only an expert with well-informed decisions and who is able to evaluate the life cycle of built environment at the design, construction, operation/maintenance, reconstruction/replacement or disinvestment stages could uphold sustainability in construction. Information on economical, environmental and societal factors is the foundation towards a successful sustainability implementation in

[1] oswald@ku.edu

construction. There are several methods of measuring the cost of sustainable design and life cycle cost analysis (LCCA) is the most prominent among them. This paper reviews different LCCA methodologies that are used to measure the costs of sustainable designs and then determines their effectiveness in measuring and presenting the benefits. It also examines the future directions to substantiate the decision-making process and convince investors about the values of sustainable designs.

LIFE CYCLE COST MEASUREMENT

It is necessary to convert economic, environmental and social benefits and externalities of sustainable design into economic cost and value, as this would allow sustainability to become measurable. Like quality, sustainability does not mean anything if it is not measurable. Transparency of business functions is critical to ensure that only genuine information will be collected and used to measure the success of sustainability implementation. Life Cycle Analysis (LCA) is a tool that measures, characterizes and evaluates resource consumption, and could incorporate a full range of environmental effects and life cycles of products, processes and activities, and measure all in scientific units. LCC is the total discounted cost of owning, operating, maintaining and disposing of a system over a period of time. LCCA is an economic evaluation technique that measures LCC (Alaska 1999). LCCA is a process of evaluating the total economic worth of a project segment by analysing initial costs and discounting future costs over the life cycle of the project segment (USDOT 2006). As such, LCC could potentially measure the costs and benefits of sustainable construction (SC), as it could be used to compare between capital and operating costs. Yates (2001) found that operating costs are typically greater than construction costs; therefore, comparing system performance requirement alternatives with respect to initial and operating costs could maximize net savings and values (Fuller 2006). Most importantly, LCCA measures the value of products and projects, and can be treated as an ideal measurement method for sustainability of construction design.

Designers can also gain insights of environmental and economic trade-offs by applying LCA and LCCA (Arpke and Hutzler 2005). There is a positive impact of LCCA application at the design, bidding and construction phases (Arditi and Messiha 1999). There is also a need of a multidimensional life-cycle approach that could provide a comprehensive and balanced analysis on sustainable design as proposed by Lippiatt (1999).

Osman and Ries (2004) used LCA to determine life-cycle impact analysis of energy systems as a useful tool to outline system configurations that could minimize environmental impacts. Blanchard and Reppe (1998) applied Global Warming Potential (GWP) and LCC to illustrate that using energy efficiency strategy and material could potentially reduce life cycle energy consumption in buildings. Junnila and Horvath (2003) suggested that practical applications of comprehensive environmental LCA could be applied to the design and management of environmentally conscious office buildings.

MODELS FOR LIFE CYCLE COST ANALYSIS

LCCA measures the total cost of facility ownership that includes costs of acquiring, owning and disposing of a built environment. According to Marshal and Petersen (1995), LCC of a project alternative can be denoted by the following:

$$LCC = I + R + E + OM\&R - S \qquad (1)$$

Where, I is the initial investment cost, R, E, OM&R and S are the PV of replacement, energy, operation, maintenance and repair costs, and the PV of salvage, respectively. The following alternative formula illustrates the discounted future costs of PV mathematically and summarizes the value into a single LCC calculation (Marshal and Petersen 1995):

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t} \qquad (2)$$

Where, C_t is the sum of all relevant costs, less any positive cash flow as salvage value, occurring in time period t; N is the number of time periods in the study period; and d is the investor's discount rate for adjusting cash flows to PV. Building for Environmental and Economical Sustainability (BEES 2006), adopted by the National Institute of Standards and Technology, follows the LCCA calculation method as shown in the following equation (Fuller 2006):

$$LCC = I + Repl - Res + E + W + OM\&R + O \qquad (3)$$

Where I, is the initial cost; E and W, are the PV of operational expenses for energy, water and other utilities; OM&R, is the PV of non-fuel operating, maintenance and repair costs; Repl, is the PV of capital replacements cost; Res, is the PV of its remaining value at the end, or at the time of replacement; and O is the PV of finance, charges and taxes, and non-monetary benefits or costs. Salem *et al.* (2003) developed the following formula to illustrate a risk-based LCC model that integrates PV calculation method with Monte Carlo simulation as shown in the following equation;

$$LCC_N = C_i + C_{fN} + Cmo_N + Cu_N - Sv_N \qquad (4)$$

Where, N is the number of simulation iterations; C_i is the initial capital cost; C_{fN} is the cost of failure (rehabilitation); Cmo_N is the cost of operation and maintenance; Cu_N is the user cost due to failure; and Sv_N is the salvage value.

COST IMPLICATIONS OF SUSTAINABLE DESIGN

Katz (2003) and Hanscomb (2005) found that most developers and contractors have to pay a 0–2% premium for a green building, though Matthiessen and Morris (2004) insisted that this has to be done within project's limited budget. Warnke (2004) also found that "sustainable" buildings can cost up to 2% more than conventional ones. Building developers would normally share the burden of excess cost with their tenants (Yates 2001).

Investor priorities

Hanscomb (2005) demonstrated that property owners could yield a payback of at least 10 times the initial investment in 20 years time even though they had to invest an additional 2% more initially. Thus, investing as much as 2% extra for a sustainable building would make a lot economic sense for the long-term investors but not for the short-term speculators. Even the long-term investors would put economic profits above social and environmental concerns. Alternatively, if the resale values of their investments would be affected by environmental and social concerns, the treatment of both concerns at the project development phase would be different. For example, the market value of a typical US home rises 20 times than that of its energy savings PV (Lützkendorf and David 2005). A small investment to improve energy saving of homes could produce significant financial returns through higher home resale value. However, long-term ownership of properties is the only rationale why LLC would be used in a project at all.

The economic pillar of sustainable design (Cost Bottom-Line)
The economic pillar of sustainability requires both economic justification and financial benefits from implementing sustainability. Success in the construction realm has traditionally been based on cost, schedule, design changes and safety (Beheiry *et al*. 2006). This aligns more closely to the economical pillar of sustainable design. Beheiry *et al*. (2006) hypothesized that sustainable method would yield lower-risk and, therefore, more economically attractive. Preliminary results of their study implied that a correlation between corporate commitment to sustainable economic practices and better-planned projects.

Changes with zero or minimal added costs
Most of the opportunity of sustainable design that adds no additional cost to a project would have to originate from designers. For example, designers have to identify a proper building orientation that could result in maximizing thermal comfort and reducing heating demand (Katz 2005). Many of the Leadership in Energy and Environmental Design (LEED) credits do not require additional cost to comply (Matthiessen and Morris 2004). Furthermore, significant savings could be derived from energy and water use reduction, and the reuse of salvaged materials (XENERGY 2000). In addition, a study on “green school” found that every 1% additional investment yielded over 30% of returns (Katz 2005).

Commitments to higher investment costs
Green roofs, commissioning, high-performance fixtures, photovoltaic panels, system measurement and verification, certified wood and low-flow or waterless sanitary fixtures may result in higher initial construction costs. However, several studies suggested that energy and water-efficient fixtures and the use of natural gas water heaters produce desirable results when compared to conventional appliances (Arpke and Hutzler 2005). Investors may find it hard to swallow such cost increase if they are not convinced that additional economic benefits could be derived from exploiting these environmental and societal variables.

Costs and benefits involving arguable worth and values
At present, environmental and societal costs do not have tangible economic values. They remain subjective with volatile values that make conversions into economic costs rather difficult. For example, a reduction of symptoms of illnesses and employee absenteeism and an increment in worker productivity have been found in many sustainable buildings (Lützkendorf and David 2005). However, it is still difficult to measure the actual cost of such benefits, though it is easier to express that in term of values. Some researchers felt that such information and data could not be tangibly quantified, and this has been the greyest area of confirming the projected financial benefits of sustainable design (XENERGY 2000).

An area of major debate surrounds the installation of higher efficiency but more expensive heating, ventilating and air-conditioning systems. Studies have claimed that such systems have led to healthier indoor environment; however, very few studies could agree on how to quantify the health benefits. In another example, a study on several Massachusetts's schools highlighted evidences of the benefits from improved environmental quality. Their study further quantified the benefits of energy and water savings, waste reduction and reduced emission (their results may vary if different assumptions were used). However, they could not quantify the benefits from increased student learning and reduced teacher turnover (Katz 2005). Profit-oriented businesses could not rely on "values" to make decisions.

WEAKNESS OF LCCA

Most studies agreed on the framework and benefits of current LCCA measurement techniques and generally agreed upon its ability to optimize total cost vs. operating benefits and its ability to generate products with lower maintenance costs and a better life cycle (Arditi and Messiha 1999). However, Arditi and Messiha (1999) indicated the need of formal guidelines that describe utilization method, published values for different parameters used in LCCA and the development of standard software. Kalinger (1999) highlighted some of the apparent weakness in LCCA that include:

- *Study Period:* because the time scale for LCCA may not necessarily be the same as the physical life of construction components.
- *Discount rate*: the real discount rate should either be the actual cost of borrowing or the rate of return of developers' best opportunity.
- *Salvage/residual value*: Salvage is negligible at the end of service period while the residual value should be considered only if it falls within the study period.
- *Forecasting*: Major forecasting errors are caused by the valuation of intangible costs, risks, uncertainty and inflation.

The replacement period in LCCA also poses some issues. It is very difficult to predict exactly when a particular material needs replacement. LCCA relies only on LCA for most of its inputs; as such, the weakness of LCA gets carried through automatically. Horvath (2004) mentioned that the problems with boundary definition, data acquisition, data quality, uncertainty and interpretation of results to be the most significant with LCA studies. He further pointed out that applying different assessment techniques on the same material may yield radically different results if different assumptions, data sources and assessment scopes are applied. Horvath and Hendrickson (1998) also noted that there is an articulated need for LCA studies, as well as better metrics and data, for sustainable development decision making.

Performing an LCCA may greatly increase the likelihood of choosing a more responsible and economically feasible project option though there may still be several uncertainties. However, such uncertainty could be overcome by applying sensitivity analysis that could identify uncertain input values with the greatest impact, determine and control calculation variability, and simulate different scenarios to establish the break-even point and analysis. Salem *et al*. (2003) utilized a risk-based approach to predict uncertainty in LCCA by incorporating probabilities of occurrence of different LCCs of an infrastructure unit. Their study concluded that the outcome could better inform decision makers on the expected level of risk. Their analyses also appear to make LCCA more reliable. The major challenge for LCCA is to judicially address social and environmental costs of sustainable design. At present, social and environmental variables are very unstable and difficult to quantify.

EXTENSION OF EXISTING LCCA MODELS

As discussed before, the most daunting task to legitimize LCCA is to translate environmental and social values into economic cost. LCA, if carried out with required care considering all the pertinent environmental factors, could evaluate the cost of environmental impacts, which can directly be used in an economical evaluation. Thus far, there is no proven method to evaluate social costs. The social costs include missed opportunities for job training and employment, community involvement in reshaping local built environments and neighbourhood stability (Leigh and Patterson 2004). The best approach so far is to use "value" to replace cost. However, value is often meaningless to many profit-oriented organizations.

Osman and Craighill (2006) indicated the need of an extended LCA that considers social and economic impacts. While assessing the social costs, both financial and external costs need to be accounted for (Rich 2006). Therefore, the social costs structure can be modelled into:

Net Social Cost, C_{SOC} = Financial Cost + External Cost – Offsetting Benefit (5)

Where Financial Costs are the expenditures made to own or operate the system and External Costs are the broader costs borne by members of society other than those who use the system. Offset benefits, if any, must also be included. The overall cost of a sustainable design can be best represented by the following cost-benefit model, which is represented by the weighted average of individual cost impact:

$$\text{Total cost} = (\sum\text{Economical} + \sum\text{Environmental} + \sum\text{Social})\ \text{costs}$$

$$\sum\text{Economical cost} = a\,E_1 + b\,E_2 + c\,E_3 + \ldots\ldots\ldots\ldots\ldots.. + z\,E_n$$

$$\sum\text{Environmental cost} = a\,EN_1 + b\,EN_2 + c\,EN_3 + \ldots\ldots\ldots.. + z\,EN_n$$

$$\sum\text{Social cost} = a\,S_1 + b\,S_2 + c\,S_3 + \ldots\ldots\ldots\ldots\ldots... + z\,S_n$$

Where, a, b, c,.... and z are the coefficient relating to respective impacts; E_1, E_2, E_3,...., and E_n are the cost impact due to different economical factors. EN_1, EN_2, EN_3,…, and EN_n are the cost impact due to different environmental factors; and S_1, S_2, S_3,…, and S_n are the cost impact due to different social factors.

A new LCCA model for any study alternative incorporating environmental and social costs has been proposed by extending the economic cost formula from Salem *et al.* (2003), which also gives due consideration to risks as

$$LCC_N = C_{ECON} + C_{ENVN} + C_{SOCN}$$

Where C_{ECON} = PV of Net Economical Cost (same as the LCC_N in Equation 4)

C_{ENVN} = PV of Net Environmental Cost for the alternative (from LCA)

C_{SOCN} = PV of Net Social Cost for the alternative

FUTURE RESEARCH

Quantifying the social and environmental LCC to offset the increase in investment cost and establishing overall feasibility in economic terms can convince investors about the benefits of sustainable design. However, the key challenge remains on gathering reliable data for an accurate LCC. LCCA involves data from an extremely long period of time, starting from the design phase to the end of life of a building. The construction industry is extremely diverse where the designers and contractors rarely communicate with facilities managers and thus do not know what really happen to their design in the long run. Most of the LCC calculations at the design and construction stages are either assumptions or projections. Further research by the authors found that there are two potential approaches to resolve the reliability issue. The first approach is to collect LCCA data of buildings from the initial stage to the end of life. This approach will yield extremely reliable analysis but it requires an extensive amount of information and time period. The second approach is to conduct simulation using assumed or some actual data. This could potentially resolve the problem of extensive data collection while taking care of reliability at the same time.

The authors have also started efforts to identify significant factors that drive the life cycle of a building and its components. Different types of building and their components have different life cycle performance and identification is needed of the significant sustainability factors that drive building life cycle. An extended mathematical model incorporating all the pertinent cost and benefit parameters and the potential risks as devised in this paper is expected to be useful to translate the social and environmental costs of sustainable design into economic terms. The model can be a helpful decision making tool in selecting the best among different project alternatives. The validation and calibration of this model is a challenging task for the future research, which would require acquisition of real data. Further research to establish the consistency and stabilize the variables of the model is also necessary to determine more accurately the cost of sustainable design.

REFERENCES

Alaska, Department of Education and Early Development (1999). *Life Cycle Cost Analysis Handbook.* 1Ed.

Arditi, D and Messiha, H M (1999) Life Cycle Cost Analysis (LCCA) in Municipal Organizations. *ASCE Journal of Infrastructure Systems*, **5**(1), 1–10.

Arpke, A and Hutzler, N (2005) Operational life-cycle assessment and life-cycle cost analysis for water use in multioccupant buildings. *ASCE Journal of Architectural Engineering*, **11**(3), 99–109.

BEES (2006) *BEES 3.0*. Building for Environmental and Economical Sustainability Available online: http://www.bfrl.nist.gov/oae/software/bees.html (accessed 10 October 2006).

Beheiry, S M A, Chong, W K and Haas, C T (2006) Examining the business impact of owner commitment to sustainability. *ASCE Journal of Construction Engineering and Management*, **132**(4), 384–92.

Blanchard, S and Reppe, P (1998) *Life cycle analysis of a residential home in Michigan.* University of Michigan.

Carassus, J (2004) *The construction sector system approach: an International framework.* International Council for Research and Innovation in Building and Construction, CIB Pub. No. 293.

Fuller, S (2006) *Life cycle cost analysis*. National Institute of Standards and Technology. Available online: http://www.wbdg.org/design/lcca.php (accessed 1 November 2006).

Hanscomb (2005) *The cost implications of LEED: A presentation*. New York: Hanscomb Faithful and Gould.

Horvath, A (2004) Construction materials and environment. *Annual Review Environmental Resources*, **29**, 181–204.

Horvath, A and Hendrickson, C (1998) Steel versus steel-reinforced concrete bridges: environmental assessment. *ASCE Journal of Infrastructural Systems*, **4**(3), 111–17.

Junnila, S and Horvath, A (2003) Life-cycle environmental effects of an office building. *ASCE Journal of Infrastructure Systems*, **9**(4), 157–66.

Kalinger, P (1999) Applying life cycle cost analysis to roofing decisions. *In: North American Conference on Roofing Technology*, CRCA, Canada.

Katz, G (2005) *National review of green schools: costs, benefits, and implications for Massachusetts*. Westborough, MA: Massachusetts Technology Collaborative.

Leigh, N G and Patterson, L M (2004) *Construction and demolition debris recycling for environmental protection and economic development, practice guide # 7*. Southeast Regional Environmental Finance Center, University of Louisville.

Lippiatt, B C (1999) Selecting cost-effective green building products: BEES approach. *ASCE Journal of Construction Engineering and Management*, **125**(6), 448–55.

Lützkendorf, T and David, L (2005) Sustainable property investment: valuing sustainable buildings through property performance assessment. *Building Research Information*, **33**(3), 212–34.

Marshal, H E and Petersen, S R (1995) Life-cycle costing. *In: Mechanical Estimating Guidebook for Building Construction*. 6Edn. New York: McGraw-Hill, Inc.

Matthiessen, L F and Morris, P (2004) *Costing green: A comprehensive cost database and budgeting methodology*. Davis Langdon.

Ochoa, L, Ries, R, Matthews, H S and Hendrickson, C (2005) Life cycle assessment of residential buildings. Proceeding paper. In: *Construction Research Congress: Broadening Perspectives*, ASCE, Reston, VA.

Osman, A and Ries R (2004) Life-cycle impact analysis of energy systems for buildings. *ASCE Journal of Infrastructure Systems*, **10**(3), 87–97.

Rich, B (2006) *Economics of waste recovery and recycling*. Available online: http://www.wasteresources.wi.gov/docview.asp?docid=5771&locid=83 (accessed 11 November 2006).

Salem, O, Abourizk, S and Ariaratnam, S (2003) Risk-based life-cycle costing of infrastructure rehabilitation and construction alternatives. *ASCE Journal of Infrastructure Systems*, **9**(1), 6–15.

USDOT (2006) *Improving transportation investment decisions through life-cycle cost analysis.* US Department of Transportation, Federal Highway Administration. Available online: http://www.fhwa.dot.gov (accessed 10 September 2006).

Warnke, D M (2004) *Making the business case for sustainable design in the department of defense*. Air Force Institute of Technology, Wright-Patterson AFB OH School of Engineering and Management.

XENERGY Inc. and SERA Architects (2000) *Green city buildings: Applying the LEED rating system*. Report for Portland Energy Office.

Yates, A (2001) *Quantifying the business benefits of sustainable buildings*. Building Research Establishment, Centre for Sustainable Construction.

ACCURACY OF ESTIMATING WHOLE LIFE COSTS

Mohamed A. El-Haram[1], R. Malcolm W. Horner[1] and Sasa Marenjak[2]

[1]*Construction Management Research Unit, Division of Civil Engineering, University of Dundee, Dundee, DD1 4HN, UK*
[2]*Croatian Institute for Bridge and Structural Engineering, Zagreb, Croatia*

Whole life costing (WLC) is now a requirement for all UK government tenders and private finance initiative schemes. Accurately forecasting the whole life costs of constructed projects is vital to the survival of any business. It is even more important to the companies who take responsibility for designing, constructing, operating, maintaining and ultimately decommissioning constructed projects. Whenever an estimate is generated, estimators and their clients want to know how close the figures are to reality. This paper addresses the meaning of accuracy, describes the important factors that affect it and the uncertainty inherent in making forecasts of project whole life costs. The paper also suggests how the accuracy of whole life cost prediction can be estimated and improved by taking due account of, for example, the WLC process, integration of the supply chain, education and training, use of proper tools and techniques and data which are both reliable and accurate.

Keywords: central limit theorem, estimating accuracy, life cycle, whole life costing.

INTRODUCTION

In the past 15 years whole life costing has become an integral part of building economics. There have been four main drivers in the UK: (1) the introduction of the private finance initiative (PFI) and public–private partnership (PPP) in 1992; (2) a demand from owners and clients for evidence of what their costs of ownership will be (Egan 1998); (3) the introduction of the Treasury procurement guidance note – no. 7: ‘Whole life costs’ (HM Treasury 2000) by the Office of Government Commerce which states that ‘all procurement must be made solely on the basis of value for money in terms of whole life costs’; and (4) sustainable construction initiatives. All these initiatives have the following principles in common: (a) an acknowledgment of the need for a longer term view which emphasizes a whole life approach to the management of construction projects; (b) the shift from selecting projects based only on initial capital investment to a consideration of future costs as well; and (c) the need to establish the link between the life cycle phases (design, construction, operation, maintenance and disposal/recycle) of built assets as well as the link between the whole life supply chain members.

Whole life costing includes all costs and revenues associated with the design, build, operation, maintenance and disposal of a building as shown in Figure 1. According to ISO-BS 15686, Part 5 (ISO 2006) WLC can be defined as: ‘economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability’.

[1] m.elharam@dundee.ac.uk

Life cycle cost analysis is an engineering and economic evaluation tool for choosing among alternative project investments and operating and maintenance strategies by comparing all the significant differential costs of ownership over a given time period in equivalent economic terms (El-Haram and Horner 1998). It takes into consideration the building specification requirements to assess and optimize the whole life costs of a building, satisfying the client and/or user requirement. ‘It therefore provides an equitable comparison on a quantitative basis amongst competing designing Authors and authorship options within the same decision-making process, in order to select the most appropriate and cost-effective design option’ (Flanagan *et al*. 1987).

Accurately forecasting the cost of future projects is vital to the survival of any business. Whenever an estimate is generated, cost estimation analysts want to know how close the figures are to reality. Generally, the estimators will not know exact costs until the period for which the costs were estimated is completed. In construction, one measure of accuracy is the deviation from the lowest acceptable tender received in competition for a project (Morrison 1999). Ashworth and Skitmore (1999) defined accuracy simply as the absence of error, that is, the smaller the error the higher the accuracy and vice versa. According to Asiedu and Gu (1999), the accuracy of an estimate is inversely proportional to the span of time between the estimate and the event.

Traditionally, estimators do not know the exact construction cost until the project is built and commissioned. In the case of PFI projects, estimators do not know the cost of a project until the end of the concession period. In general, estimators do not know the exact whole life costs of a project until the end of its life (disposal). Naturally, each estimator will want the cost of every element to be as accurate as possible given the data they have at the time they generate it.

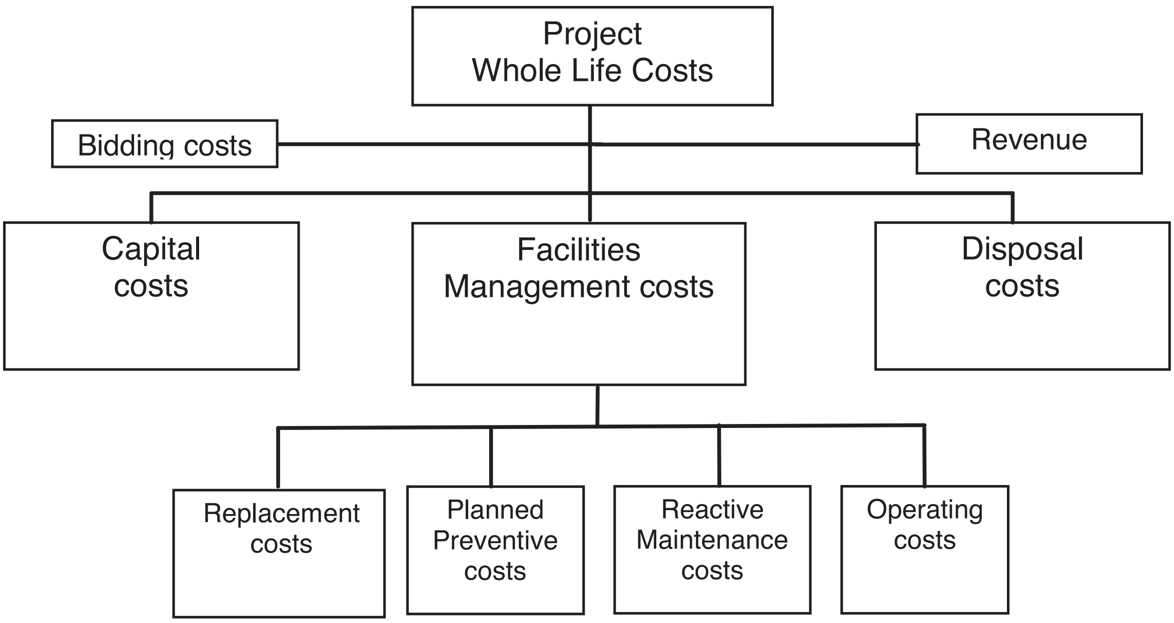


Figure 1: Main whole life cost elements

FACTORS AFFECTING ACCURACY

This section describes the significant factors that could have an impact on the accuracy of whole life costs and suggests ways that might improve the level of accuracy of whole life costing. The estimator must keep in mind the importance of the following factors:

- whole life costing methodology;
- availability of data;
- method of estimation;
- experience, skill and judgement of the estimators.

The above factors are drawn from a review of the literature (Al-Hajj and Horner 1998; Akintoye and Fitzgerald 2000) and the experience of the authors.

WHOLE LIFE COSTING METHODOLOGY

In response to the initiatives mentioned in the introduction, various methodologies have been developed to improve the implementation of whole life costing. However, their application depends on the circumstances of projects and requirements of the clients involved. The lack of an accepted industry standard methodology for implementing whole life costing has a significant impact on the accuracy of estimating whole life costs. The recent publication of ISO-BS 15686 Part 5, 'Whole life costing' will encourage a more consistent approach to whole life costing and may increase the level of accuracy. However, the Standard does not suggest methods of measurement for whole life cost elements. The authors have developed an initial framework for a standard method of measurement for whole life costs of construction projects. It defines:

- how a cost element is to be divided into the separate costs of tasks/activities/resources in the breakdown structure;
- what is included and excluded for each cost element;
- the data and information to be given in estimating the cost element;
- the units in which the cost elements and work activities are to be expressed;
- how the cost element is to be measured for the purpose of calculating cost.

The framework mirrors that used in the Civil Engineering Standard Method of Measurement and the Standard Method of Measurement for Building Works, both of which have given rise to similar methods for producing and pricing bills of quantities. An example of the proposed standard method of measurement for whole life costs is provided in Appendix 1.

Data availability

The accuracy of the output data from whole life cost modelling depends on the accuracy of the input data. Therefore, the suitability and availability of the cost data used when estimating will have an important bearing on accuracy. The data and information which are needed to estimate whole life costs include the cost of materials, manpower and equipment and/or plant that are directly required to estimate the cost of construction, maintenance, replacement, operation tasks and other whole life cost elements such as rates, security, utilities, catering and waste management.

Other data which are also required to estimate whole life cost elements include building elements' life expectancy, frequency of carrying out a task (e.g. planned preventive maintenance, cleaning, etc.), required level of performance, the physical characteristics of a building, discount rate and the period of analysis.

One of the main barriers to the successful implementation of whole life costing is the lack of available historic data on elements of whole life cost (El-Haram and Horner 1998). Even where the data exist they are neither consistent nor in a form that can be used for effective whole life cost analyses. This lack of available useful data is partly a consequence of the lack of an acceptable whole life costing data structure. One of the key steps in successfully implementing a consistently and widely used whole life costing methodology is to create or adopt a standard data structure. The objectives of a standard breakdown structure are:

- to provide the framework for defining cost which enables cost estimators to prepare whole life cost estimates;
- to identify all activities throughout the life cycle that will generate costs.

El-Haram *et al*. (2002) have developed a framework for a whole life cost data breakdown structure for the building industry. The proposed structure is divided into five levels. The top-down hierarchy of the data structure is project level, phase level, category level, element level and task level, as shown in Figure 2. Each level is broken down further. For example, level 2 is broken down into a series of phases such as capital, facilities management and disposal. The structure is supported by a pool of data and information that is related to the factors influencing the estimation of whole life costs.

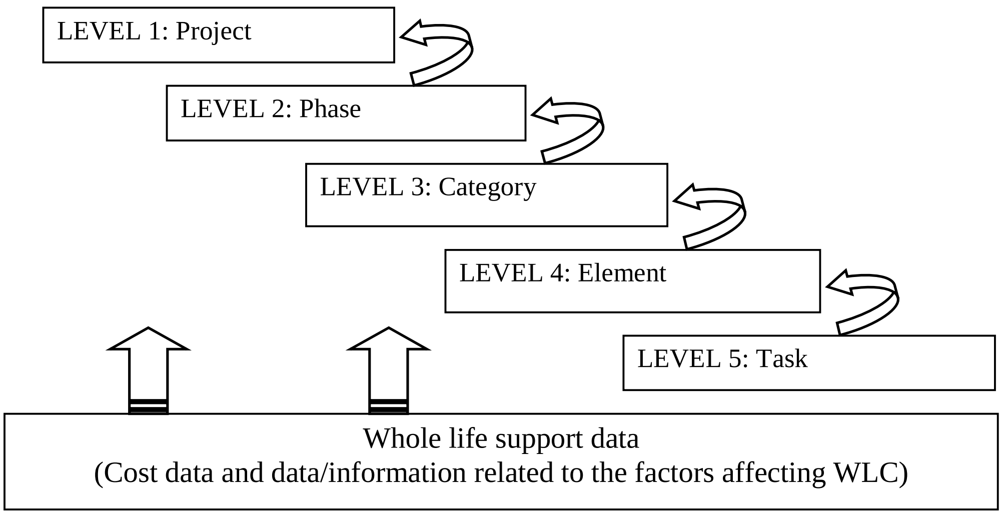


Figure 2: Levels of whole life costs data structure

The use of reliable historical data would significantly improve the accuracy of estimation of whole life costs. It is therefore highly desirable to establish a whole life cost data portal through which companies can collect and benchmark the whole life costs for every project.

Method of estimation

Various methods are available to estimate the elements of whole life costs including parametric, regression, analogous and more detailed approaches (Blanchard and Fabrycky 1991). Different estimating methods have different inherent errors. The inherent errors in the method are linked to the detail with which the estimate is produced and the variability of the cost data it employs. The choice of estimating method depends on the stage of the project, the type of each cost element (e.g. construction, replacement, etc.) and the availability of data and information. The level of accuracy of cost prediction is likely to increase and improve as the level of detail in which estimates are prepared and the knowledge about proposed design parameters increase.

Experience, skill and judgement of the estimators

Life cycle cost estimators not only attempt to estimate capital costs of construction project options which is a problem in itself, but they must also predict future costs of maintenance, replacement, operating and other related costs as well as revenues. On top of this, they must forecast the economic factors to be used: discount rate, project life and the lives of the various components used, together with their repair intervals and replacement cycles, unexpected use of the project, unusual events such as change of ownership, and the influence of future fiscal policies (Avery 1989).

Regardless of the stage of the project, estimators should compile and analyse data on all the contextual factors that can influence costs. Even cost information derived from within the same building type (school, hospital, etc.) is influenced by such factors as size, complexity, height, specification and intensity of use which combine to produce a wide range of building costs (Marenjak 2004). In addition, the estimator must make a number of adjustments to the cost data derived from one time, location and market situation to the anticipated time, location and market situation relevant to the new project. The reliability of the cost estimate and the level of accuracy of cost predictions are dependent upon the professional experience, skill and judgement of the estimator which can be improved through increasing their involvement in whole life cost estimating and through training. Estimating whole life costs is a team effort requiring the integration of the skills of all the key members including designer, builder, facility manager, end user and others. This will enhance the feedback from those who operate and maintain the facility to those who design new projects.

UNCERTAINTY

The major difficulties in applying life cycle costing in practice are related to the prediction of future behaviours and events such as:

- the behaviour of people in terms of their use of, and response to, the project (much of which will relate to non-economic issues and will be difficult to measure);
- the behaviour of materials, components, and mechanical and electrical systems;
- the future uses of the project, and the environmental conditions to which it may be exposed;
- the financial and economic conditions that influence the relationship between present and future costs;
- difficulty in controlling the total costs of ownership which are affected by administrative procedures or political decisions driven by short-term gains.

These factors are never constant, but vary from year to year. Some of them can, at least, be considered, analysed and evaluated: others cannot even be imagined at the time of estimation. The difficulties in forecasting the physical and economic life of a project stem from many factors, such as life expectancy, deterioration rate, mean time between failures, discount rate, taxation, functional, technological, social and legal regimes, location, fashion and environmental obsolescence (El-Haram and Horner 1998). Consideration of these variables can be a source of many complexities in undertaking a whole life cost appraisal. Whole life cost decisions therefore involve a considerable amount of uncertainty, which makes it very difficult to carry out economic evaluations with a high degree of reliability. Examples of the techniques used to deal with uncertainty are conservative benefits and cost estimating, sensitivity analysis, risk-adjusted discount rate, mean-variance criterion and coefficient of variance, decision analysis and simulation (Flanagan *et al.* 1987; Marshall 1991). No single technique can be labelled as best for treating uncertainty and risk. What is best will depend on many things such as availability of data, availability of resources and computational aids, user understanding, level of risk exposure of the project and the size of the investment (Marshall 1991). If the reliability of WLC analysis is to be improved, the sources of uncertainties must be dealt with as an integral part of the whole life cycle process.

LEVEL OF ACCURACY IN WHOLE LIFE COSTING

The level of accuracy varies from project to project and from phase to phase within the same project. The accuracy can change as the design progresses from the feasibility to the detailed stage. Whole life cost analysis during the feasibility and preliminary design stages may require the use of basic accounting techniques and the model may be rather simple in construction (Blanchard and Fabrycky 1991). On the other hand, whole life cost analysis during the detailed design stage may be more detailed and may rely on a more or less sophisticated cost breakdown structure. During the feasibility design stage of a building, available data are limited and the cost analyst must depend primarily on the use of various parametric cost estimating techniques in the development of cost data. The cost estimates at this level have average accuracies of ±20% to ±30% (Asif 1988; Zakieh 1991). As the building design progresses to preliminary design stage, the average level of accuracy of cost estimation is ±10% to ±20% (Asif 1988; Zakieh 1991). Finally, at the detailed design stage, all of the information about the building is known. A contractor's accuracy of estimating at this stage (tender stage) is on average ±6% to ±10% (Asif 1988; Zakieh 1991). It is very difficult to assign a level of accuracy for whole life cost estimates at the bidding stage due to the level of uncertainty. Uncertainty is inherent in making future forecasts of operation and maintenance, replacement cost and any other future costs. The expected level of accuracy at this stage is likely to be worse than the level of accuracy at tender stage for traditional projects. This means that the average accuracy of estimating whole life costs at the bidding stage is likely to be ±10% or higher. The level of accuracy of estimating whole life costs depends on the factors which are described in the previous section. However, the current level of accuracy must be accepted until a better model and more reliable data and information become available.

Illustrated example

This hypothetical example is not based on any real data and it is only presented to illustrate the level of accuracy of the whole life costs of a project. The levels of accuracy shown in Figure 3 are for demonstration only and do not necessarily represent actual levels in practice. From the literature the accuracy of estimates of construction cost at the tender stage is on average ±10%.

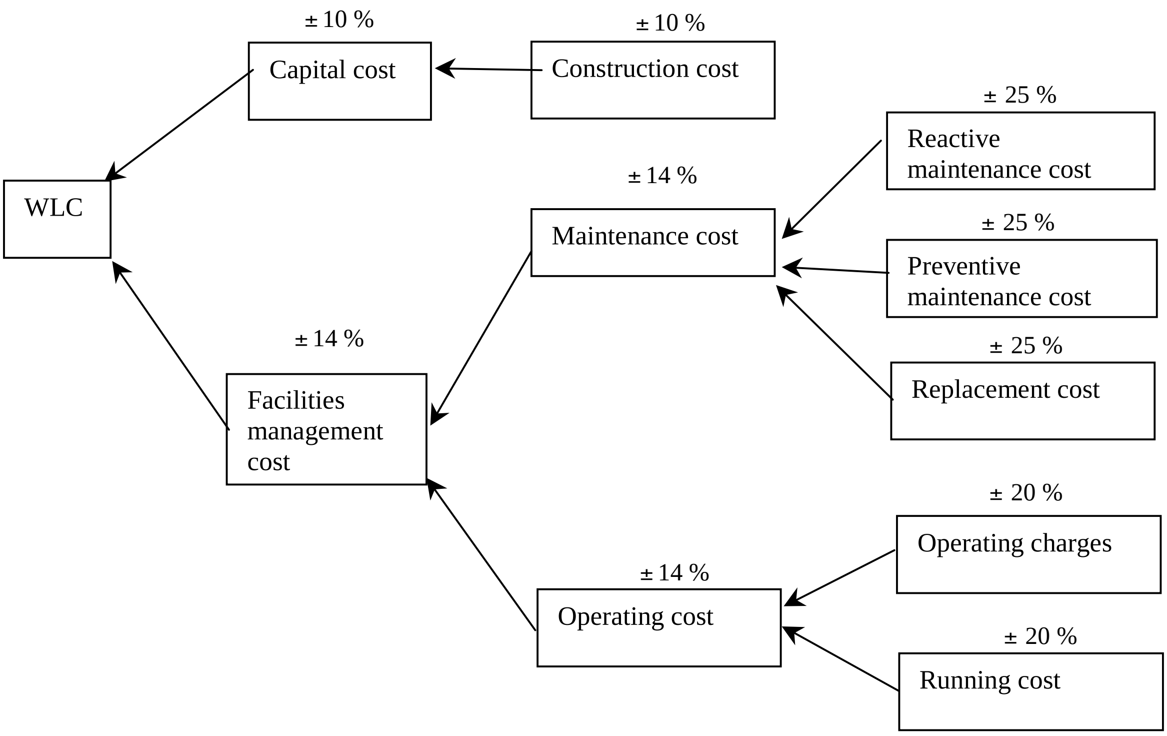


Figure 3: Illustrated example of level of accuracy of WLC

However, the authors think that the level of accuracy of estimating facilities management costs might be of the order of ±25%, while operating and running costs might be estimated to ±20%. Despite these relatively large inaccuracies, thanks to the central limit theorem (see Appendix 2), the accuracy of whole life costs is ±7%. This level of accuracy is considered to be generally acceptable, at least until better models and more reliable information are available.

CONCLUSIONS

The paper has shown that there is no quick fix that will immediately make estimators estimate whole life costs more accurately. Improved estimates will come about as a result of improvements in whole life costing methodology, integration of the supply chain, education and training, good project management, use of proper tools and techniques, sufficient resources and time, and a good reliable cost database. It could be several years before the construction industry has enough data from which better estimates of whole life costs can consistently be made. There are many issues that require further clarification to accurately estimate the WLC of a project. These include:

- better understanding of the factors that influence project costs in order to improve the estimation accuracy at each stage of a project;
- establishing the level of accuracy at each stage of a project or for each category of whole life costs;
- better understanding of how the estimator’s experience influences accuracy;

- the reliability of historical project data;
- the ways in which the choice of an estimation method and the use of cost estimation software influence estimation accuracy.

The paper has also shown that whole life costs deal with an unknown future, characterized by a variety of uncertainties. It is therefore imperative that any life cycle model incorporates the treatment of uncertainties. Fortunately and fortuitously, the central limit theorem works to the estimator's advantage. As long as there is a sufficient breakdown of costs, this law of 'swings and roundabouts' will serve to reduce the error in the final estimate of whole life costs, despite the larger levels of inaccuracy in the cost build-up.

REFERENCES

Akintoye, A and Fitzgerald, E (2000) A survey of current cost estimating practices in the UK. *Construction Management and Economics*, **18**, 161–72.

Al-Hajj, A and Horner, R M W (1998) Modelling the running costs of buildings. *Construction Management and Economics*, **16**, 459–70.

Ashworth, A and Skitmore, R M (1999) *Accuracy of estimating*. London: E & FN Spon.

Asiedu, Y and Gu, P (1998) Product life cycle cost analysis: state of the art review. *International Journal of Production Research*, **36**(4), 883–908.

Asif, M (1988) *Simple generic models for cost-significant estimating of construction project cost*, Unpublished PhD Thesis, Department of Civil Engineering, University of Dundee.

Avery, D W (1989) Life cycle costs and future uncertainties. Paper presented at the Conference on Spreadsheet Applications to Building and Quantity Surveying Processes, Sheffield City Polytechnic, UK.

Blanchard, B S and Fabrycky, W J (1991) *Life-cycle cost and economic analysis*. New York: Prentice Hall.

Egan, J (1998) *Rethinking construction*, Report of the Construction Task Force to the Deputy Prime Minister, DETR. London: HMSO.

El-Haram, M and Horner, M. (1998) Factors affecting life cycle cost in the construction industry. *In*: J Knezevic (Ed.) *Proceedings of the 8th International Logistics Symposium*, Exeter, UK, 229–40.

El-Haram, M A, Marenjak, S and Horner, R M W (2002) Development of a generic framework for collecting whole life cost data for the building industry. *Journal of Quality in Maintenance Engineering*, **8**(2), 144–52.

Flanagan, R and Norman, G (1999) *The accuracy and monitoring of quantity surveyors' price forecasting for building work.* London: E & FN Spon.

Flanagan, R, Kendell, A, Norman, G and Robinson, G D (1987) Life cycle costing and risk management. *Construction Management and Economics*, **5**, S53–S71.

HM Treasury (2000) Whole life costs: Treasury procurement guidance note – no. 7. London: HMSO.

Horner, R M W and Zakieh, R (1996) Characteristic items: a new approach to estimating and controlling construction projects. *Construction Management and Economics*, **14**, 241–52.

ISO (2006) ISO/DIS 15686 Buildings and constructed assets – service life planning, Part 5. Whole life costing. British Standards Institution/The International Organisation for Standardisation.

Marenjak, S (2004) *A generic approach to minimising whole life costs in the building industry*, Unpublished PhD Thesis, Department of Civil Engineering, University of Dundee.

Marshall, H E (1991) *Economic methods and risk analysis techniques for evaluation building investment: a survey*, CIB Report 136 for W55.

Morrison, N (1999) *The accuracy of quantity surveyors' cost estimating*. London: E & FN Spon.

Zakieh, R (1991) *Quantity-significant and its application to construction projects modelling*, Unpublished PhD Thesis, Department of Civil Engineering, University of Dundee.

APPENDIX 1: EXAMPLE OF A STRUCTURED FRAMEWORK FOR ESTIMATION OF WLC

Element: Windows

Unit of measurement: **m**^{2} (total area of windows)

Capital cost		Facility management cost		Disposal cost
Design cost	**Construction cost**	**Maintenance cost**	**Operation cost**	
Definition Cost of all design tasks, which are required to design windows	*Definition* Cost of windows including costs of all sashes, frames, linings, and trims, ironmongery and glazing, lintels, and sills, cavity damp-proof courses and work to reveals of openings	*Definition* Costs of maintenance tasks (reactive, preventive and replacement) which are required to retain the window in or restore it to an acceptable level of condition/performance or to a state in which it can perform its required function(s)	*Definition* The cost of all activities which are required to operate the window and maintain its function(s)	*Definition* Cost of all work needed to dismantle and dispose of windows and the value of any recycled items
Measurement rules *Including:* • Specifications • Drawings	**Measurement rules** *Including:* • Metalwork • Glazing • Woodwork (e.g. frame) • Surface decoration (painting) • All accessories (sills, cavity damp-proof courses, ironmongery)	**Measurement rules** *Including:* Reactive maintenance • Wear and tear • Misuse and vandalism Preventive maintenance • Predetermined (scheduled) • Condition based (scheduled and/or on request condition survey) Replacement • Predetermined (scheduled) • Condition based (scheduled and/or on request condition survey)	**Measurement rules** *Including:* • Cyclic cleaning	**Measurement rules** *Including:* • Type of dismantling and disposing • Land fill tax
Excluding: • Management and overheads (company specific) • Profit	*Excluding:* • Work in forming structural opening • Exterior blinds and the like • Sunshields and screens • Site preliminaries • Management and overheads (company specific) • Profit	*Excluding:* • Maintenance tasks (reactive and/ or replacement) caused by early defects (construction or manufacturing) • Maintenance tasks (reactive, preventive and/or replacement) during warranty period. • Replacement tasks not included in reactive and preventive maintenance • Designed-out maintenance tasks • Management and overheads (company specific) • Profit	*Excluding:* • Cleaning task caused by misuse, vandalism (graffiti) • Management and overheads (company specific) • Profit	*Excluding:* • Value of recycled items • Management and overheads (company specific) • Profit

Coverage rules • All cost of resources stated in the general principles • Cost of unavailability of design on time • Profit	**Coverage rules** • All cost of resources stated in the general principles • Profit	**Coverage rules** • All cost of resources stated in the general principles • Cost of unavailability • Cost of secondary damage (in case of reactive task) • Profit	**Coverage rules** • All costs of resources stated in the general principles • Cost of unavailability • Profit	**Coverage rules** • All cost of resources stated in the general principles • Disposal of windows (landfall tax) • Value of recycled items • Profit
Supplementary information • Location/region of the building • Function of the building • Size and height of the building • Type of structure of window • Type of finishes of window • Size of the area of window • Intensity of use, level of risk • Environmental issues (external and internal environment) • Required level of services • Manufacture & supplier recommendations • Quality of material of window and its sub-elements • Quality of workmanship • Failure consequences • Condition of the building's elements and services • Others (user expectation, etc.)	**Supplementary information** • Type of frame • Intensity of use • Method of operating the windows (manual or automatic) • Size of the windows, type of glazing (e.g. single, double) • Construction procedures – fixing in position • Fire resistance	**Supplementary information** • Durability and reliability of window and its sub-element • Life expectancy of window and its sub-elements • Quantity of maintenance tasks (reactive maintenance and reactive decoration, planned preventive maintenance (PPM), condition survey and life cycle replacement) • Duration of maintenance and support task (time to restore the failure, decoration task time required to perform PPM, condition survey and replacement) • Mean time between failure (MTBF) of components • Expected number of maintenance tasks (reactive maintenance and reactive decoration, PPM, condition survey and life cycle replacement) • Frequency of maintenance tasks (decoration, PPM, condition survey and life cycle replacement) • Age of the windows • Failure consequences • Others (misuse, user expectation, etc.)	**Supplementary information** • Type of operating task, e.g.: • Clean glass, wash windows internally • Clean glass, wash windows externally • Clean frames internally • Clean frames externally • Clean sills • Type of windows cleaning equipment • Quantity of operating tasks • Expected number of operating tasks • Frequency of operating task • Others (e.g. user expectation, etc.)	**Supplementary information** • Age of the windows • Type of frame • Size of the windows, type of glazing (e.g. single, double)
Method of estimation • Fee related (as a percentage of construction costs) • Unit rate costing • Operational costing	**Method of estimation** • Unit rate costing • Operational costing	**Method of estimation** • Unit rate costing • Operational costing	**Method of estimation** • Unit rate costing • Operational costing	**Method of estimation** • Unit rate costing • Operational costing

APPENDIX 2: CENTRAL LIMIT THEOREM

The central limit theorem states that in any sequence of repeated trials the standard sample mean approaches the standard normal curve as the number of trials increases (Horner and Zakieh 1996). In these circumstances, the mean of the sum of the trials is the sum of the means of individual trials, and the standard deviation of the sum is equal to the square root of the sum of the standard deviations of each trial squared. The measure of variability of most value statistically is the coefficient of variation (CV). This is the standard deviation, expressed as a percentage of the mean. The central limit theorem (Horner and Zakieh 1996) assumes that:

- the accuracy of each cost element is independent;
- the error in the WLC model of the project is equally distributed across all the cost elements (i.e. the mean model accuracy and variance are constant for all cost elements).

Let a_i be a random variable representing the accuracy of estimation of the *i*th cost element in the WLC model, (i = 1, 2, …, n), where n is the total number of cost elements in the model. The accuracy of the estimate of a single cost element within the model is defined as the percentage difference between the estimated cost and the actual expenditure.

$$\mathrm{a}_i = \frac{EC_i - AC_i}{AC_i} \times 100$$

where:

a_i = accuracy of the *i*th cost element

EC_i = estimated cost of the *i*th cost element (say preventive maintenance)

AC_i = actual cost of the *i*th cost element.

The accuracy of estimation of each cost element has a distribution with mean μ_i and variance δ_i^2. The coefficient of variation of each cost element is

$$CV_i = \frac{\sqrt{\delta_i^2}}{\mu_i} \times 100\%$$

Assuming the a_i values are independent, then the distribution of the sum of a_i, $\mathrm{A_s}$ has a mean

$$\mu_s = \mu_1 + \mu_2 + \ldots\ldots + \mu_n = \sum_{i=1}^{n} \mu_i$$

and variance

$$\delta_s^2 = \delta_1^2 + \delta_2^2 + \ldots\ldots + \delta_n^2 = \sum_{i=1}^{n} \delta_i^2$$

Assuming that the mean model accuracy and variance are constant for all cost elements in each cost category of whole life costs, then

$$\mu_1 = \mu_2 = \ldots\ldots = \mu_n$$

$$\delta_1^2 = \delta_2^2 = ... = \delta_n^2$$

so

$$\mu_s = n \times \mu_i$$

and

$$\delta_s^2 = n \times \delta_i^2 \, .$$

It follows that the coefficient of variation of any cost category such as facilities management or the whole life cost of a project is:

$$CV_s = \frac{\sqrt{\delta_s^2}}{\mu_s} \times 100 = \frac{\sqrt{n \times \delta_i^2}}{n \times \mu_i} \times 100 = \frac{\sqrt{\delta_i^2}}{\sqrt{n} \times \mu_i} \times 100$$

Thus,

$$CV_s = \frac{CV_i}{\sqrt{n}}$$

where:

CV_s = coefficient of variation of the accuracy of the cost category;

CV_i = coefficient of variation of the accuracy of each cost element within the cost category (constant for all cost elements in each cost category);

n = number of cost elements in the cost category.

FAMILY LIFE CYCLE AND THE PLANNING OF MULTIFAMILY HOUSING

João Alberto da Costa Ganzo Fernandez,[1] Roberto de Oliveira[2] and Luiz Fernando Heineck[3]

[1]*Professor of the Construction Department, Federal Center of Technology of Santa Catarina, Brazil*
[2]*Professor of the Civil Engineering Department, Federal University of Santa Catarina, Brazil*
[3]*Professor of the Production Engineering Department, Federal University of Santa Catarina, Brazil*

The literature shows a series of studies that demonstrate the importance of the family life cycle on the housing choice process. Based on this, 935 potential apartment purchasers of Florianópolis (SC) were interviewed with the purpose of identifying the most valued architectural attributes in each phase of family life cycle and whether there is a statistical relationship between the respective phase and the relative indispensability of each attribute. With the exception of the following attributes: sunny bedrooms, individual water meter and ample kitchen, on which a consensus as to importance exists, there is a logical and distinct pattern of priorities. While childless couples prioritize the living room, barbecue on the balcony and the pool, those who have children prioritize the playground and the service bathroom. When children grow older, families start to value attributes related to space and privacy such as maid room, hobby box, two parking spaces, two master bedrooms and acoustic insulation. Buyers in the last phase of the family life cycle, the empty nest, differ from the others by the attributed importance to the independence for the service entrance and the nice view from the living room. The desired number of bedrooms is greater during the phases of family expansion and smaller during childless as well as contraction phases. The results were submitted to chi-square testing that reveals association between family life cycle and the following apartment attributes: number of bedrooms, playground, two parking spaces, service bathroom, service entrance, maid room, two master bedrooms, at most two apartments per floor, good view from the living room, pool, hobby box, hot water system, ample kitchen with table, sophisticated security system, Jacuzzi, small wash basin and individual water meter. The existence of these associations demonstrates that the variable family life cycle is relevant and may be used to support – at least in relation to those attributes – an architectural programming for a market-oriented multifamily building.

Keywords: architecture, design, family life cycle, marketing, multifamily projects.

INTRODUCTION

The first step in the architectural design process is the creation of the architectural programming or as Silva said (1991): ‘the statement of the requirements (necessities, aspirations and expectations) to be satisfied by what will be constructed’.

The Architecture College prepares the future professional to decipher and elaborate the programming for single families, not providing the necessary theoretical tools (market research) for a multifamily project. In these cases, when there isn’t a specific family and their needs aren’t knowledgeable, the architect adopts a passive posture in

[1] jganzo@terra.com.br

terms of the project, accepting the architectural programming determined by the property developer. This programme on the other hand, is based on pure intuition, market perception and on the consultation of the empirical knowledge of real estate brokers.

To reduce the chance of errors in the formulation of this programme, ingredients of flexibility considering the spatial arrangement of the project are added or subtracted many times, allowing it to adapt to the individual variations of each family nucleus. Nevertheless, according to Brandão (1997), modifications in the project resulting in the individualization of apartments in multifamily buildings imply reduced productivity owing to the increase of complexity, reduction of continuity and loss of the repetition effect.

Alexander (1979) correlates the great number of changes during the construction process with the lack of architectural quality of the original project in relation to the potential market. The absence of quality, referred to by Alexander, actually explains the inadequacy of the original project regarding the potential market segments.

Therefore, projects must be conceived considering the focus of a segmentation market. The segmentation strategies are directly linked to the increase of profit, which occurs when the economic value for the consumer is higher than the cost to create this value. ‘The objective of a segmentation strategy is to take one shot at the market and not a burst of machine gun fire’ (Engel *et al*. 2000).

The key question here is: how to correctly segment the housing market?

This work presents the potential of using the family life cycle (FLC) concept as a significant segmentation strategy for a correct definition of the architectural programming for multifamily housing projects.

THE SEGMENTATION OF THE CONSTRUCTION MARKET

The identification of the segmentation strategies adopted by the construction companies to define their standard architectural programming isn’t always an easy task. Frequently, the ways of segmenting get mixed up and interact. Sometimes, what seems to be segmentation based on income actually is a psychographic segmentation based on life style, in other situations it’s just a geographic segmentation chosen from the experience of a local construction company.

In spite of the former difficulties mentioned, a general trend towards a primary segmentation based on income/social class (demographic segmentation) and location (geographic segmentation) can be observed. Both are highly correlated: distinguished locations are directly related to higher income.

There is secondary segmentation on family size (projects of apartments with a variable number of bedrooms); sensitivity towards the marketing factor (distinguished finishing, allowed flexibility strategies and promotional prices).

However, even if some empirical segmentation is practised, the absence of more elaborated studies, mainly concerning the preferences of specific segments for certain property characteristics and specific locations, impedes the property developer from taking advantage of a well-directed project (with attributes that actually add value) or even avoiding changes during construction which may increase the final cost of the apartment.

The determination of potential segments in the construction business is decisively influenced by the location of the lots. According to Meyer and Haddad (2001), 'For all companies the opportunity to purchase a lot is the structural step of the entire process'.

Usually acquired beforehand for the market's sake, the lot, more specifically the attributes of its location, serves as a starting point for the segmentation process of the multifamily housing product and for the determination of the architectural programming. The cost of the lot will blend with the total construction area, conditioning decisively the price per unit, not depending on quantity or the size of the units.

Since the possibilities of the finishing standards are restricted to the ones considered coherent with the value of the location (primary segmentation on income), the morphologic characteristics (number and type of compartments) and general use equipment account for the role of the differential elements among the various project possibilities (secondary segmentation). This is why, traditionally, a housing offer is simplified and divided by number of bedrooms and location. In this way, the conclusion is that a primary segmentation by income emerges almost naturally because of the price and the characteristics of the lot's location.

In a regional context, Fernandez (1999)[1] demonstrated the importance of the family cycle when choosing the location of the apartments, and Oliveira (1998), through a post-occupational study, concluded that there are distinct preferences concerning the attributes of the same apartment for different stages of the family life cycle. Both studies were developed in Florianópolis, SC. Macedo (2004) reached the same conclusion as Fernandez and Oliveira while interviewing 49 residents of apartments in Maringá, PR.

The international literature presents various studies that indicate the importance of the family life cycle in the decision process of choosing a home (e.g. Rossi 1955; Speare 1970; Pickvance 1974; Clark and Onaka 1983; Schmitz and Brett 2001).

THE FAMILY LIFE CYCLE

The family life cycle is formed by the many stages of specific necessities that families go through over life's course. Regarding housing, these necessities comprise the most obvious, such as accessibility, equipment and physical space, as well as symbolic values like neighbourhood status, building facade and the quantity of natural green environment around it.

Rossi (1955) emphasizes the importance of the family life cycle affirming that the modal family voluntarily leaves the old home, impelled by changes in its size and composition, which demands a larger home.

Practically all families know beforehand the size of home they need. Some search only the neighbourhoods they find interesting. Others search areas near relatives or locations of determined social class level.

As time goes by, families become more sensitive towards the physical and social environments provided by the home's location. The need for space is the most important of all alterations caused by the life cycle, as well as the main attribute of a house. The larger the house, the larger its capacity to accommodate the needs generated by the alterations of the family life cycle. Small homes only fit the first and last stages of the life cycle. As the children grow up and spend more time away from the home, the quality of the external environment becomes more important to the family. The families ‘climbing’ the social ladder are more sensitive to the social aspects of the location. Such climb is the main motivational factor of their changes.

Clark and Onaka (1983) while analysing the results of many researches on why people move, confirmed the importance of the family life cycle as the structural element for the main reasons: for young couples, the cost of maintenance of the home and the property issue are the main reasons for the move; for families in the intermediate stages (couples with small children or teenagers), the size issue and finished quality of the home and property are the most relevant and finally for families in a more advanced stage with adult children still living in the home, neighbourhood factors and accessibility are the most important. In other words, the authors recognize that each stage has distinct necessities concerning housing.

The family life cycle stages are particularly difficult to classify and measure. The classical sociological context identifies the following phases: prenuptial; married with no children; the birth of the firstborn to the last child born (expansion phase); the birth of the last child until the departure of the firstborn; departure of the firstborn until the departure of the last one born (contraction) and after the departure of all children (empty nest) (Glick and Parke 1964).

The logical comprehension of the changing process is of great interest to the real estate market. A science that started to take its first steps in the middle of the last century (20th century) in the United States. As Wells and Gubar (1966) and Gilly and Enis (1982) confirm, the family life cycle models serve to define the potential segments, since they characterize stages and mark transitions associated with changes in the consumption pattern.

The Wells and Gubar (1966) model was a target for criticism for it considered the traditional standard post-war family, where the birth rate was high (baby boom) and the divorce rate was low. A new model proposed by Murphy and Staples (1979) includes the cycles and recycles of divorce and future marriage. However, this model only recognizes the cycles initiated by marriage. Stapleton (1980) tried to solve this problem adapting a new life cycle model to modern times, more dynamic, including in its structure the cycles and recycles of divorce or widowhood and a new marriage.

Gilly and Enis (1982) also added bachelorhood, couples that couldn’t or did not want to have children and single parents, to a very complete temporal diagram in a matrix format, with 14 stages interlacing each other.

Engel *et al.* (2000) also affirm that the homes that are not inhabited by traditional families, as the ones described by Gilly and Enis (1982), suffer the effects of temporal cycles, which are very important to marketing. As an example the American singles are quoted: they represent a quarter of the consumers of new homes. This implies changes in the projects: fewer bedrooms, less space for the dining room, more space for the kitchen (which is turning into a living room), more luxurious suites, bathrooms with a ‘spa’ and a living room with ‘high-tech’ entertainment.

As a conceptual reference, it’s worth observing the models of Pickvance and Speare created in the 1970s. Both were considered responsible for the demonstration of the relationship between the family life cycle, residential mobility and housing consumption.

The Pickvance model (1974) considers seven stages: (1) prenuptial; (2) couple with no children; (3) birth of the first child; (4) birth of the last child; (5) departure of the first child; (6) up to the departure of the last child and (7) empty nest.

According to Speare (1970), however, the FLC is composed of six stages: (1) singles, widows(ers) or divorced up to age 45; (2) newlyweds during the year of matrimony; (3) couples up to age 45 and oldest child up to age 5; (4) couples with children at school age, between 5 and 18 years old; (5) couples over 45 at the phase of family contraction; and (6) singles, widows(ers) or divorced over 45 years of age.

The author concludes in her research that though age and stage of the family cycle seem to represent the same concepts, they should not be confused. People in the same age group, but in a different stage of the family life cycle have different behavioural patterns concerning residential mobility. Similarly, people in the same life cycle stage, but in a different age group also act differently: the ones that get married later in life move less than the ones that get married earlier.

This exception suggested by Speare is relevant, since it opposes the subsequent models, which mistakenly divide the stages only by age groups, as the Burns and Gleber 1986 models. They consider five stages: (1) 25 to 34 years old; (2) 35 to 44 years old; (3) 45 to 54 years old; (4) 55 to 64 years old; and (5) over 65.

McCarthy (1976) doesn’t speak of the family life cycle, but of the inhabitant’s life cycle. For him the resident’s life cycle is divided into nine stages: (1) young and single with no children up to age 45; (2) young couple with no children; (3) young couple with a small child up to age 5; (4) young couple with oldest child between 6 and 18; (5) mature couple (husband at age 46) with oldest child at age 18; (6) mature couple with no children living at home; (7) singles, widows(ers), divorced, mature and no children living at home; (8) singles, widows(ers), or divorced with children younger than 18 living at home; and (9) other cases, such as widows(ers) that live with their married children and grandchildren.

The correct way to call them would be divisions instead of stages, since they can be mutually exclusive among each other.

Krisjanous (2001) highlights the importance of a study on the specific necessities of the empty nest for the real estate market. The increase in number of elderly couples resulting from the advances in medicine and consequently the increase in life expectancy, combined with the decrease of birth rate is causing an emerging search for real estate products that are new and adequate to the elderly. The author sub-segments the empty nest stage into three categories with distinct necessities: the young elderly (65–74 years old), the intermediate elderly (75–84) and the old elderly (over 85 years old). Burns and Grebler (1986) idealized a more pertinent solution to the population aging problem: the construction of granny flats attached to the apartment of their grown-up children.

It is evident; therefore, that the knowledge of the observable preferences of each stage of the family life cycle can provide the basis for establishing a secondary segmentation strategy to improve and better define the architectural programming.

METHODOLOGY

The attributes of the apartment preferred in each stage of the family cycle will be identified and ranked through descriptive statistics, considering the results of the research on market requests brought about by UFSC – Universidade Federal de Santa Catarina in a partnership with SINDUSCON – Industry and Construction Union, with 935 potential apartment consumers during the last five Real Estate Exhibitions that took place in Florianópolis (2001, 2002, 2003, 2004 and 2005). In these researches, a standard questionnaire was used with the objective of identifying the main desires, aspirations and necessities of the city's real estate market.

To identify how the variable 'family life cycle stage' is relevant as a segmentation element, and consequently for the elaboration of the architectural programming, the degree of association between that variable and 27 other variables that represent the attributes of the apartment were tested. The statistical tests used were the chi-square (x^2) and the concordance correlation coefficient.

According to Barbetta (1998) the chi-square test (x^2) is the oldest statistical test, as well as the most used in social research. It allows testing the significance of the association between two variables, qualitative or categorical.

When the variables are independent, there is a null hypothesis (H^o), since frequencies observed tend to be close to the frequencies that are expected. In this case, the value of x^2 must be small. However, a larger value in the x^2 statistic points to the fact that the differences between the observed frequencies and the expected frequencies shouldn't be merely casual; in other words, there is an association between the two variables.

With this test it was possible to detect which are the attributes of the apartment that have an effective correlation with the life cycle stage, and that, consequently must be observed by the project engineer while defining the architectural programming, once the probable family life cycle stage of the future residents of the property is known beforehand.

Besides the chi-square test, which possesses inferential characteristics (allows extrapolating conclusions of the sample to the universe), the contingency coefficient will be verified so as to estimate the degree or strength of the association between the two categorical variables.

All the potential apartment consumers in the city of Florianópolis in the following years (2002, 2002, 2003, 2004 and 2005) were considered as the object-population. The sampling criteria are non-probabilistic for convenience, since just one part of the object-population is accessible to collect the sample data (the visitors of the Real Estate Exhibition that are potential buyers and that agree to answer the given questionnaire).

Because of the factual impossibility of carrying out a probabilistic sampling, the results of the research must be considered with caution. Another factor that limits the explanatory power of the collected samples is selectiveness in terms of the buying potential of the public visiting the exhibition. Because it was carried out in a 'shopping centre', an environment with a well-defined socio-economic standard of the participants (middle-class, high-class), it's natural that the sampling produces this sort of inclination.

Only the interviewed people that fit into one of the five stages of the classical life cycle were considered: couples with no children, with small children, with teenagers, with adult children living at home and couples in the empty nest. The singles, widows(ers), divorced and any other situation that is outside the traditional family standard were excluded.

The research is limited by space and time variables; therefore, its results reflect the reality of the city of Florianópolis, Brazil, during the years that were researched. The transposition of the conclusions to other cities with distinct economic and cultural realities must only be an indicative character.

Since it is a descriptive research, there is no intention to determine the nature of the relationship between the variables or the factors that contribute to the occurrence of the phenomenon that was studied; these may be the subject of future explanatory research.

RESULTS

Ranking of preferences per stage of the family life cycle

Table 1 expresses the percentage of individuals, of each stage, that consider each one of the attributes (26) essential (wouldn't buy an apartment in the absence of the attribute).

Table 1: Number of cases and percentages of each stage where each attribute was considered essential

Attributes	**No children**		**Small children**		**Teenage children**		**Adult children**		**Empty nest**		**Total**	
	417	**44.60**	**176**	**18.82**	**204**	**21.82**	**96**	**10.27**	**42**	**4.49**	**935**	**100.00**
	cases	**%**	**cases**	**%**	**cases**	**%**	**cases**	**%**	**cases**	**%**	**cases**	**%**
Sunny bedrooms	292	70.02	140	79.55	164	80.39	76	79.17	34	80.95	706	75.51
Individual water meter	173	52.58	86	61.87	97	62.99	61	69.32	26	72.22	443	59.38
Roomy kitchen	197	47.24	109	61.93	126	61.76	64	66.67	30	71.43	526	56.26
Piped hot water	175	41.97	94	53.41	117	57.35	52	54.17	28	66.67	466	49.84
Balcony	195	46.76	97	55.11	100	49.02	49	51.04	24	57.14	465	49.73
Renowned company	150	35.97	86	48.86	104	50.98	44	45.83	23	54.76	407	43.53
Two garage spaces	125	29.98	81	46.02	108	52.94	65	67.71	19	45.24	398	42.57
Sophisticated security	123	29.50	80	45.45	81	39.71	42	43.75	20	47.62	346	37.01
Common function area	143	34.29	61	34.66	79	38.73	28	29.17	8	19.05	319	34.12
Small pantry	113	27.10	56	31.82	71	34.80	40	41.67	16	38.10	296	31.66
Beautiful view	91	21.82	48	27.27	87	42.65	38	39.58	21	50.00	285	30.48
Acoustic insulation	64	25.60	28	29.17	35	33.98	32	43.84	6	25.00	165	30.22
Barbecue on the balcony	111	26.62	47	26.70	69	33.82	38	39.58	13	30.95	278	29.73
Hobby box	67	16.07	44	25.00	63	30.88	32	33.33	12	28.57	218	23.32
WC in the living room	67	16.07	40	22.73	51	25.00	29	30.21	14	33.33	201	21.50
Service bathroom	50	11.99	51	28.98	59	28.92	26	27.08	10	23.81	196	20.96
Service entrance	37	8.87	37	21.02	54	26.47	25	26.04	19	45.24	172	18.40
Playground/court	30	7.19	45	25.57	37	18.14	13	13.54	2	4.76	127	13.58
Sophisticated facade	30	7.19	21	11.93	27	13.24	11	11.46	7	16.67	96	10.27
Maid's room	14	3.36	27	15.34	39	19.12	12	12.50	4	9.52	96	10.27
Two suites	20	4.80	18	10.23	37	18.14	16	16.67	4	9.52	95	10.16
Max. two apts. per floor	15	3.60	20	11.36	32	15.69	13	13.54	9	21.43	89	9.52
Swimming pool	23	5.52	19	10.80	29	14.22	9	9.38	3	7.14	83	8.88
Fitness centre	16	4.86	12	8.63	17	11.04	7	7.95	5	13.88	57	7.64
Whirlpool bath	16	3.84	17	9.66	18	8.82	6	6.25	5	11.90	62	6.63
Only one apart. per floor	1	0.24	4	2.27	4	1.96	0	0.00	1	2.38	10	1.07
Sum of the percentages		**583.05**		**805.35**		**870.75**		**879.44**		**887.30**		

The total and increasing sum of the percentages of what was considered essential shows that families are becoming more demanding as they move ahead in the family life cycle. A possible explanation is that the experience of residing makes people more critical and demanding regarding a home.

Table 2 shows the rank of each attribute for each of the stages of the FLC. The following guidelines have been extracted from recent criticisms of real abstracts. This may help to overcome some of the most frequent problems.

Table 2: The ranking of each attribute per stage of the family life cycle

Attributes	No Children	Small children	Teenage children	Adult children	Empty nest	Total
Sunny bedrooms	1	1	1	1	1	1
Individual water meter	2	3	2	2	2	2
Roomy kitchen	3	2	3	4	3	3
Piped hot water	5	5	4	5	4	4
Balcony	4	4	7	6	5	5
Renowned construction company	6	6	6	7	6	6
Two garage spaces	8	7	5	3	9	7
Sophisticated security	9	8	9	9	8	8
Community function area	7	9	10	15	18	9
Small pantry	10	10	11	10	11	10
Beautiful view from the living room	13	13	8	11	7	11
Acoustic insulation	12	11	12	8	15	12
Barbecue on the balcony	11	14	13	12	13	13
Hobby box	14	16	14	13	14	14
WC in the living room	15	17	17	14	12	15
Service bathroom	16	12	15	16	16	16
Service entrance	17	18	16	17	10	17
Playground/court	18	15	19	19	25	18
Sophisticated facade	19	20	23	22	19	19
Maid’s room	25	19	18	21	23	20
Two suites	22	23	20	18	22	21
Max. two apartments per floor	24	21	21	20	17	22
Swimming pool	20	22	22	23	24	23
Fitness centre	21	25	25	24	20	24
Whirlpool bath	23	24	24	25	21	25
Only one apart. per floor	26	26	26	26	26	26

All five stages find the following attributes a priority: sunny bedrooms (unanimous in all stages as the most important attribute), individual water meter, roomy kitchen, piped hot water and living room balcony. The first stage of the family life cycle (couples with no children) stands out from the others for attributing a higher relative value to the community function area and the swimming pool. The second stage (small children) is noticed because of the relative importance given to the playground and the service bathroom. Two garage spaces are essential for the intermediate stages of the family life cycle – teenage and adult children and the stage mentioned last is the one that values acoustic insulation the most and two suites. The empty nest stage presents rather peculiar results. In contrast to the rest, it values the independent service entrance (maybe due to cultural issues) not attributing much importance to two garage spaces.

Concerning the number of bedrooms, there is a growing demand from the couples with no children stage (mode = 2 bedrooms) up to the teenage children stage (mode = 3 bedrooms). From there on, the number of bedrooms starts to decline until the empty nest stage (mode = 2 bedrooms), as Table 3 illustrates.

Table 3: Mean and mode of the desired number of bedrooms per stage of the FLC

Family life cycle	Mean	Mode
Couples with no children	2.44	2.00
Small children	2.90	3.00
Teenage children	3.06	3.00
Adult children	2.95	3.00
Empty nest	2.57	2.00

Association between the preferences and the family life cycle stages

The statistical tests chi-square[2] and contingency coefficient (see Table 4) demonstrated associations between the family life cycle stages and the variables: number of bedrooms, playground, two garage spaces, service bathroom, service entrance, maid's room, two suites, max. two apts. per floor, beautiful view, swimming pool, hobby box, piped hot water, roomy kitchen, sophisticated security, whirlpool bath, WC in the living room and individual water meter. In other words, the degree of indispensability or priority of these variables for the people interviewed isn't mere accident, it is the product of the family life cycle stage in which the person is currently. Therefore, they are key variables in a process of segmentation per family life cycle stage.

Table 4: Association among the attributes of the apartment and the family life cycle

Attributes	$\chi 2$	p	C
Number of bedrooms	184.75	0.00000	0.41
Playground/court	84.43	0.00000	0.29
Two garage spaces	68.62	0.00000	0.26
Service bathroom	64.37	0.00000	0.25
Service entrance	64.36	0.00000	0.25
Maid's room	63.37	0.00000	0.25
Two suites	48.58	0.00000	0.22
Max. two apartments per floor	45.71	0.00000	0.22
Beautiful view from the living room	44.73	0.00000	0.21
Swimming pool	41.72	0.00000	0.20
Hobby box	34.20	0.00004	0.19
Piped hot water	33.65	0.00005	0.19
Roomy kitchen	27.65	0.00054	0.17
Sophisticated security	24.36	0.00169	0.16
Whirlpool bath	24.08	0.00223	0.16
WC in the living room	23.58	0.00269	0.17
Individual water meter	23.08	0.00325	0.17
Community function area	21.36	0.00625	0.15
Small pantry	21.21	0.00660	0.15
Renowned construction company	21.12	0.00684	0.15
Acoustic insulation	16.18	0.03987	0.17
Sunny bedrooms	15.79	0.04543	0.13
Maid's room	15.08	0.05746	0.14
Barbecue on the balcony	13.42	0.09820	0.12
Sophisticated facade	13.32	0.10120	0.12
Only one apart. per floor	12.33	0.13687	0.11
Balcony	5.03	0.75426	0.07

CONCLUSION

Families change with time, going through many stages. This process was historically called family life cycle (FLC). The work confirmed that there are associations between the family life cycle of the individual and the degree of importance attributed to some of the main morphologic, functional and symbolic characteristics of the desired apartment, among them, the number of bedrooms. In other words, the preferences revealed are not by accident, they obey the life cycle logic. Besides this statistical confirmation, the preferences of each stage were ranked and it showed that families become more demanding as they move ahead in the life cycle. With the exception of the following attributes: sunny bedrooms, individual water meter, roomy kitchen, piped hot water and a living room balcony, for all of which there is a consensus as to importance, a logical and distinct pattern of priorities is observed. The existence of two garage spaces in the intermediate stages is highly valued (families with teenage children and adult children), while a community function area is more valued in the first stages (couples with no children or with small children). Similarly, the desired number of bedrooms also follows a logical pattern. It is higher in the stages of family expansion and lower in the contraction stages.

With knowledge of the priorities of each stage, concurrent with the preferences of the stages in which potential residents of the building are (in terms of location), it is possible to create a qualified architectural programming, which will establish the conceptual guidelines for the architectural project. This adjustment of the project towards the aspirations of the market means satisfaction of the future inhabitant and success of the commercial project.

NOTES

[1] Fernandez (1999) interviewed 60 middle class apartment dwellers in downtown Florianópolis who have recently moved, with the aim of correlating locational attributes to specific preferences for each family life cycle stage. His main conclusions were: *Couples without children:* This stage emphasizes the importance of *status*. The presumed reason for this preference may be related to the need to make a social statement. The attribute of being *close to the workplace* also appears to be significant. *Couples with young children:* As one would expect, the proximity to children's schools is the most important attribute for this segment. The attribute *square closeness* appears among the five prioritized attributes, due to the lack of leisure areas in the condominiums. *Couples with young children and adolescents:* Children's development and entry into adolescence cause a change in families' priorities in relation to the location attributes. The attribute *close to school* continues to be an absolute priority, although the attribute of a well-policed area appears in third place, revealing a concern, from the parents' view, with the safety of their children who are now more independent in their daily lives. *Couples with adolescents:* In a similar vein, safety ranks as a maximum priority in this stage, displacing *proximity to the school* in the first place. The surprise in this stage is the appearance of the attribute *closeness to the supermarket*. *Couples with young adults:* This stage is characterized by parents' and children's maturity. *Proximity to the school* is no longer prioritized, because children attend or will soon attend a more distant university. It also decreases the importance of *safety*, prioritizing some quality of life attributes such as *very green surroundings* and *peaceful place*. Among accessibility attributes, the *proximity to supermarket and conveniences* underline the pragmatic characteristic of this phase of family life. *Empty nest:* The 'empty nest' stage is distinguished from the others; children have already left home, leaving the couple to experience the remainder of their lives. This segment places neither proximity to *public leisure areas* nor *very green surroundings* as priorities, instead placing more importance on the *proximity to hospitals*. The surrounding traffic of the shopping malls is less of a concern (many do not drive any more) than the comfort that these commercial outlets offer. The *conveniences* rank in second place in the preferences, reinforcing previous statements.

[2] Significant coefficient (α) = 0.005.

REFERENCES

Alexander, C (1979) *Função da arquitetura moderna*. Rio de Janeiro: Biblioteca Salvat de Grandes Temas, Salvat Editores.

Barbetta, P (1998) *Estatística aplicada às ciências sociais*. 2ed. Florianópolis: UFSC.

Brandão, D (1997) *Flexibilidade, variabilidade e participação do cliente em projetos residenciais multifamiliares: conceitos e formas de aplicação em incorporações*, Unpublished MSc Thesis, UFSC, Florianópolis.

Burns, L and Grebler, L (1986) *The future of housing markets: a new appraisal.* New York: Plenum.

Clark, W and Onaka, J (1983) Life cycle and housing adjustment as explanations of residential mobility. *Urban Studies*, **20**, 47–57.

Engel, J, Blackwell, R and Engel, P (2000) *Comportamento do consumidor*. 8ed. Rio de Janeiro: Livros Técnicos e Científicos Editora.

Fernandez, J A C G (1999) *Preferências quanto à localização e influência do ciclo de vida familiar*, Unpublished MSc Thesis, UFSC, Florianópolis.

Gilly, M and Enis, B (1982) Recycling the family life cycle: a proposal for redefinition. *Advances in Consumer Research*, **9,** 271–6.

Glick, P and Parke, R (1964) New approaches in studying the life cycle of the family. *Demography*, **2**, 187–202.

Krisjanous, J (2001) The end of a few good years: redefining the household life cycle classification for the elderly in the 21st century. Paper presented at the Australia and New Zealand Marketing Academic Conference, Brisbane.

Macedo, M (2004) *Preferências quanto à localização e morfologia do apartamento em relação ao ciclo de vida familiar*, Unpublished MSc Thesis, UFPR, Curitiba.

McCarthy, K (1976) The household life cycle and housing choices. *The Regional Science Association*, **37**, 55–80.

Meyer, J and Haddad, E (2001) Adoção de métodos de análise de mercado imobiliário nas decisões de projeto de incorporações residenciais. Paper presented at 2nd Seminário da LARES, São Paulo.

Murphy, P and Staples, W (1979) A modernized family life cycle. *Journal of Consumer Research*, **6**, 12–22.

Oliveira, M (1998) *Os fatores determinantes da satisfação pós-ocupacional de usuários de ambientes residenciais*, Unpublished MSc Thesis, UFSC, Florianópolis.

Pickvance, C (1974) Life cycle, housing tenure and residential mobility: a path analytic approach. *Urban Studies*, **11**, 171–88.

Rossi, P (1955) *Why families move*. Glencoe, IL: The Free Press.

Schmitz, A and Brett, D (2001) *Real estate market analysis*. Washington: Urban Land Institute.

Silva, E (1991) *Uma introdução ao Projeto Arquitetônico*. Porto Alegre: Ed. da UFRGS.

Speare, A (1970) Home ownership, life cycle stage, and residential mobility. *Demography*, **7**(4), 449–58.

Stapleton, C (1980) Reformulation of the family life cycle concept: implications for residential mobility. *Environment and Planning*, **12**, 1103–18.

Wells, W and Gubar, G (1966) Life cycle in marketing. *Journal of Marketing Research*, **3**, 355–63.

ECONOMIC ANALYSIS OF HOUSING DESIGN

Renato da Silva Solano[1] and Roberto de Oliveira[2]

[1]*Faculdade de Arquitetura e Urbanismo, and Engenharia PUCRS Av. Fábio A Santos, No 1660, CEP 91720-390 Porto Alegre RS, Brazil*
[2]*Departamento de Engenharia Civil UFSC Bloco A sala 209 Campus Universitário, CEP 88040-900, Florianópolis SC, Brazil*

An economic analysis is made of two housing designs in the city of Porto Alegre (State of Rio Grande do Sul, Brazil). From the municipal approved blueprints the two designs were technically reviewed aiming at identifying possible interventions that could improve their economic performance as well as verify their principal authors' adherence to their architectural solutions. A comparison was made between the usual parametric process with the most commonly used indicators such as: construction global cost, estimation percentage services distribution participation, vertical and horizontal plans building (according to percentage participation distribution), installations and site; construction unit costs; compacity index as a key performance indicator. As conclusions, first a comparison between theoretical references and the analysed designs is presented, stressing the interventions that could be proposed to economic performance improvement for Design 1. Second, for Design 2, the repercussion on its global construction cost was analysed when the concepts of compacity index were used on the horizontal plan. In both cases the design analyses by using the shape effect have revealed that cost reductions are possible since changes could be made in the sense of reducing the number of edges and increasing the compacity index.

Key words: cost, design, estimating, housing, key performance indicators.

INTRODUCTION

This article makes a comparison between traditional Brazilian norm (ABNT-NBR 12721) cost estimation method (parametric procedures) and two other methods that are based on a building's shape. It refers only to the application of two methods in order to provide the basis for a comprehensive research. The first method deals with the amount of materials and labour costs while the second also considers the shape combined with those plan indentations that generate edges on the building; the cost impact of edges may be unperceived by the norm-based estimators, and mainly by the designers. This fact is an issue that, in the majority of projects, may lead to conflicts on the budget between designers (blueprints from office) and engineers/estimators (work on site). Literature points out the lack of designers' attention to the construction global cost (CGC) while making their decisions.

First, each of the two designs is described, then they are analysed. In Design 1 an analysis based on Mascaró's (1998) theory called Mascaró estimation method that relates design's horizontal and vertical plans, installations and temporary

[1] renato@picoralsolano.com.br

installations (such as site preparation and other related costs); after this, a study of the effect of compacity index and the balcony quality on construction costs are performed. In Design 2 an analysis of the effect of the number of edges on the general costs of construction is performed.

LITERATURE REVIEW

The comprehension of key performance indicators by designers could lead to a better understanding of impacts on construction costs of some design details. Cost analyses in early phases of the project should involve– among other measures – a search for matching the budget (within the estimation) with design propositions. The technical literature is unanimous about which design stages have the highest impact on the building's overall performance and it is the economic one that is the focus of this work (Sievert 1991; Bureau of Engineering Research 1987; Van der Mooren 1987).

Here, one of the key performance indicators is the compacity index (CI), added to the concept of economic perimeter (Mascaró 2002) that is defined as 'the perimeter of external walls passing by the internal parts of the balcony plus the perimeter of the balcony's external walls plus 50% of the external walls' and balcony's edges' (Mascaró 1998). CI is a relationship between area and perimeter, as given by the formula in row 8 of Table 1. The more compact a building is, the less cost is incurred. A circle has a CI of 100%, and square is around 85%; for rectangles, the CI starts around 60% and decreases quickly to 50% as long as the ratio between its measures increases. The study of geometric relationships goes back some decades as shown in Table 1.

Table 1: List of area comparisons by the perimeter of a closed area

Index	Equation	Author
1.Relation of shape	$\mathbf{4A/\ \pi e^2}$	Horton 1932; Haggett 1965
2. Relation of circularity	$\mathbf{4\ \pi A/P^2}$	Miller 1953
3. Relation of elongation	$\mathbf{(A/\ \pi)^{1/2}.(2/e)}$	Shumm 1956
4. Relation radial-line	$\mathbf{\sum_i(t_i\text{-}1/n)}$	Boyce and Clark 1964
5. Relation of elypsity	$\mathbf{4A/\ \pi em}$	Stoddart 1965
6. Relation of compacity	$\mathbf{A(2\ \pi f_A t^2 \eth_A)^{1/2}}$	Blair and Bliss 1967
7.Design performance	$\mathbf{100.2\ \pi(s/\ \pi)^{1/2}/c}$	March 1970
8. Compacity index	$\mathbf{2.(A\ \pi)^{1/2}.100/P}$	Mascaró 1985
9. Relation of compacity	$\mathbf{P^2/A}$	Wise 1988

Sources: 1,2,3,4,5,6, and 7 March and Steadman (1971), Martins (1999); 8 Mascaró (1985)

Notes:

A = area
C = total perimeter of the floor
S = floor area
P = perimeter of the figure
e = diameter or minor axis
m = diameter or major axis
n = number of vertices
t_i = normalized radial axes, from the centric to the vertices
t = radial axes from the centric to the small area $\eth_A$

However, those concepts are largely ignored by the majority of designers and taken for granted by the estimators because both sides operate in isolation and/or there is a lack of integration among other actors of the project's phases. Sometimes the constraint of the lot shape curbs the design towards a building's economic effectiveness owing to lack of compacity.

Another largely ignored concept is the relation of vertical and horizontal building elements. Many times designers and estimators – pressured by generalized needs of cost reductions – would like to make building cost reductions by decreasing the building's construction area. However, as it is impossible to reduce the distance between floor and ceiling (meaning the height of walls, for instance), the real final cost will not be so impacted. Table 2 shows the impact on total costs by comparing horizontal and vertical plans in the so-called 'Mascaró estimation method' (MEM). According to Mascaró, vertical plans have much more cost influence than the horizontal ones.

Table 2: MEM or relationship among horizontal and vertical plans on incurred costs (adapted from Mascaró 1998)

Element	**Percentage**
Shaping horizontal plans	26.79%
Shaping vertical plans	44.84%
Installations	24.33%
Temporary installations, site preparation and other related costs	4.02%
Total	99.98%

MEM has limitations, of course, because its use is advisable only in early design phases in order to orient the designer in relation to costs. That is the purpose of this work: to get designers, in earlier design phases, to be realistic about costs, yet not unreasonably precise.

DESCRIPTION OF THE DESIGNS

Design 1

Design 1 was conceived for the staff of a state firm foundation from user needs elicited from 5000 participants. This research indicated that 125 parking spaces were needed and also indicated the required number of elevators, the amount and dimensions of rooms of each the 96 housing units, as well as the condominium infrastructure of leisure and the building of overall systems. The land lot is in Teresópolis, and has three multi-storey buildings over columns, and the dwellings are from the second floor to the ninth floor; the water reservoir and elevator installations are over these spaces. The design of each tower can be inscribed in a rectangle of 15.75 × 27.5 metres without being constrained by the lot. It presents indentation on the façade to accommodate the core of vertical circulation and thermal devices. It also has a semi-built-in balcony on the building core that can be classified as sophisticated according to Mascaró (1998). By this is meant that the design for the balcony is elaborate. The cost impact of sophistication in design is highest when compared with second and third class. According to Brazilian norms this design is classified as similar to H8/3N (eight floors, third class of finishings, i.e. not of high quality in terms of material specification). The estimated cost using parametric method reached a construction global cost (CGC) of R$5 415 486 while with Mascaró's method it is R$5 447 072. The compacity index (CI) is 46%. The main floor plan is shown in Figure 1. As the analysis refers to estimation, details such as location in the land lot, other geometric features and other aspects are supposed unnecessary.

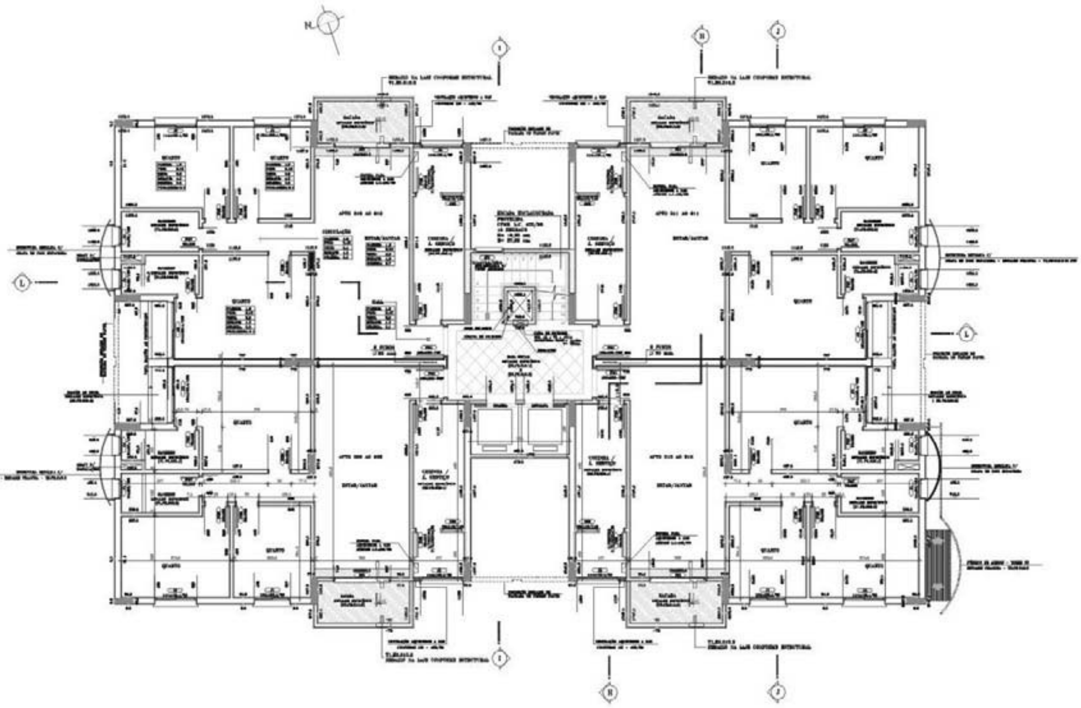


Figure 1: Design 1 main floor plan

Design 2

The conception of Design 2 was carried out by a realtor who acts in the city of Porto Alegre after consulting his/her brokers. It also is a high-rise building with an underground parking space, first floor over columns, and the dwelling units – 24 with one bedroom and 48 with two bedrooms as well as 144 parking spaces – are from the second to the thirteenth floor. According to Brazilian norms it is an H12/2N, meaning (height of) 12 floors with second class finishings. The design presents a rectangular shape in a proportion of 1:2.5 which is constrained by the lot. It also presents indentation on the façade to accommodate the core of vertical circulation. The main floor has balconies integrated with its living room. The estimated cost using parametric method reached a construction global cost (CGC) of R$6 310 000. Its CI is 64%. The main floor plan is Figure 2. As the analysis refers to estimation, details such as location in the land lot, other geometric features and other aspects are supposed unnecessary.

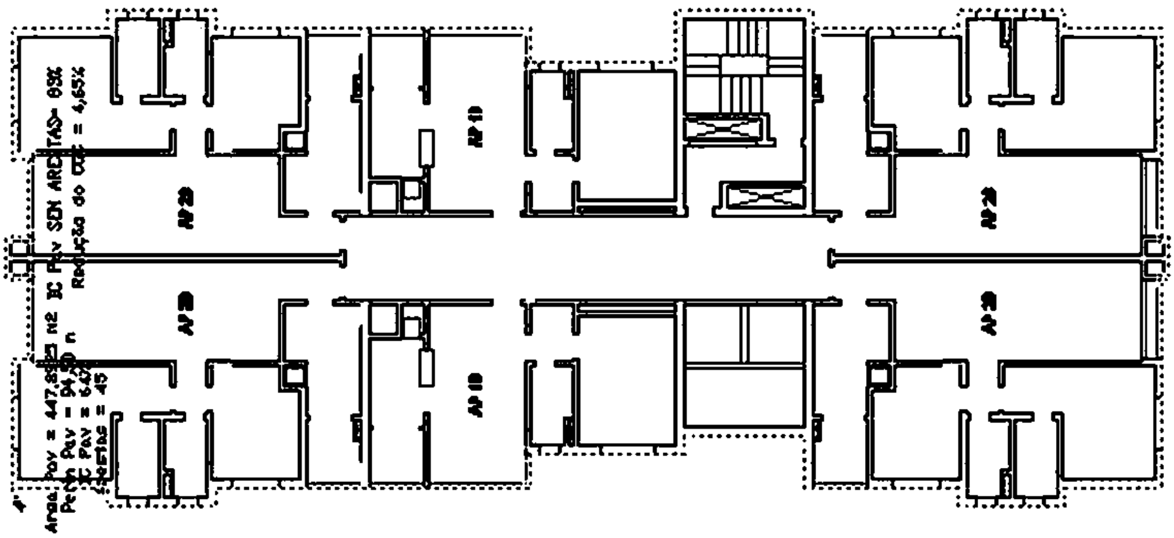


Figure 2: Design 2 main floor plan

METHOD

Design 1 analysis from economic perspective

According to Mascaró estimation method (MEM) the global cost of construction reached R$5 447 072. Table 3 shows the difference between the Brazilian norm backed methods. The overall difference is insignificant, at 0.02%.

Table 3: Differences between MEM and Brazilian norm methods

Element	% MEM	Design 1	Difference
Shaping horizontal plans	26.79%	29.8%	3.01%
Shaping vertical plans	44.84%	48.19%	3.35%
Installations	24.33%	16.92%	–7.41%
Temporary installations, site preparation and other related costs	4.02%	5.09%	1.07%
Total	99.98%	100%	**0.02%**

Following this, the influence of plan shape and the area on the total cost of the building is made using the CI (in the second column as percentage, in the third as it increases the cost also by percentage, and, in the fourth, construction costs decreasing) in eight steps named as 'action' in the first column. The first step is to downgrade the quality of the balcony, from sophisticated to simple, which results in lowering its construction cost. The other steps refer to eliminating the edges of the main floor plan in order to increase the CI and decrease the construction cost per square metre (CC/m^2). Table 4 shows those design actions, such as changing its rectangular-shaped plan, and in the last column is written the impact of the intervention.

Table 4: Actions on Design 1 towards CI and CC/m^2

Action	CI (%)	CI(+)%	CC/m^2 (–)	Comment
Original plan	46	None	None	None
01 Change for simple balcony	56	19.8	4.5%	Radical
02 Remove façade edges (rect. plan)	62	33.3	8.4%	Radical
03 Action 02 decreasing larger side	62	32.7	7.9%	Radical
04 Action 02 decreasing shorter side	60	30.0	6.9%	Radical
05 Keep only vertical circulation indentation + decreasing shorter side	51	10.7	2.6%	Radical
06 Keep only thermal devices' indentation + decreasing shorter side	55	17.8	4.0%	Radical
07 Keep only thermal devices' indentation + decreasing larger side	55	19.6	4.3%	Radical
08 Keep only vertical circulation indentation + decreasing shorter side	51	8.9	2.2%	Radical

In Table 4, the first column shows eight design measures from the original plan; the main design actions are listed. In the second column, the CI is calculated accordingly. In the third, the difference between the CI of the original plan and the one calculated as a result of each of the eight design actions. The fourth shows the difference between original cost per square metre and each one of the measures (variation of CI). In the last column comments are added to the final result for each of the eight design measures. Radical means a very marked effect on the external appearance of the building that could generate disagreement between the architect and the design consultant (in this case, engineer).

After presenting the results, and owing to the fact that the municipality had approved this design (ready for constructing), Option 1 was chosen. This choice reduced construction costs by 4.5%.

Design 2 analysis from economic perspective

This design was analysed by the CI under three options in which each one of the finishing external characteristics were kept as they were formerly proposed by the designer; only the effect of changes on geometric shape were used to evaluate the CI effect on the construction global cost indicated by square metres (CC/m^2). The shape option is indicated by the number of edges whose number directly affects CC/m^2. Table 5 shows these options.

Table 5: Actions on Design 2

Options	CI (%)	Number of edges	CGC (R$x1000)	Savings (%)
Original plan	64	45	6310	—
01 Keep plan area and adjust perimeter to 24 edges	70	24	6180	2.06
02 Keep plan area and adjust perimeter to 12 edges	75	12	6100	3.32
03 Keep plan area and adjust perimeter to 4 edges	83	4	6016	4.65

After presenting this Table to the realtor and the designer the decision made was to choose Option 2. The saving of R$210 000 on construction costs represented the sale price of two one-bedroom apartments or one two-bedroom apartment. The main reason for choosing Option 2 is because it impacts on the design only slightly while making large savings in construction costs. It is not a perfect decision, and that is why it is called an ‘option’.

RESULTS

The comparison between theoretical references and the analysed designs in the light of compacity index, vertical/horizontal shaping plans, and the number of edges has demonstrated that simple interventions in the design phase can be proposed to increase the economic performance improvement for both designs. For Design 1, using Mascaró estimation method (MEM) in which shaping of vertical and horizontal plans were considered, a negligible error of 0.02% was incurred. It means that MEM has a high level of precision, at least for this example. Following this, the action towards CI reduction has shown many design solutions that could be used, depending on owner–designer relationships and/or interests. For Design 2, the economic impact derived from the number of edges was evident and the resulting savings were exemplified by apartment’s sale price.

For both cases, the concepts of CI, vertical/horizontal shaping plans and MEM have provided the designer and owner with a clear vision of how to forecast budget conflicts with the designer and estimator. Further systematic research is called for to bring more clarification to these ideas. However, the main goal of this work is to provide two ways of balancing design propositions and their cost impacts by applying two easy and quick methods: compacity index and Mascaró estimation method.

REFERENCES

ABNT (Brazilian Association of Technical Norms) (1992) NBR 12721. Unit costs evaluation and construction estimation preparation for building condominium realtoring. Rio de Janeiro.

Martins, D N (1999) *Metodologia para determinar e avaliar a qualidade e o custo da solução geométrica do projeto arquitetônico de apartamentos*, Unpublished Doctoral Thesis, EPS, UFSC.

Mascaró, J L (1985) Classroom notes of 'economic aspects of building design'. Porto Alegre.

Mascaró, J L (1998) *O custo das decisões arquitetônicas*. 2ed. Porto Alegre: Sagra-Luzzatto.

Rosso, T (1980) *Racionalização da Construção*. São Paulo: FAUUSP.

Sievert, R W Jr (1991) A review of value engineering as an effective system for planning building projects. *Project Management Journal*, **22**(1).

Solano, R da S (2002) O custo das decisões arquitetônicas: análise de projeto e alternativas de intervenção. Paper presented at 2nd Workshop Nacional, Porto Alegre.

Van der Mooren, A L (1987) Maintenance aspects in design of mechanical systems. *In*: W W Eder (Ed.) *Proceedings of the 1987 ICED*. New York: The American Society of Mechanical Engineers, Vol. 1.

FROM CONSTRUCTION TO SERVICES: THE CLIENT INTERFACE AND THE CHANGES IN PROJECT AND SERVICES GOVERNANCE IN PPP

Elisabeth Campagnac[1]

Laboratoire Techniques, Territoires et Sociétés, Ecole des Ponts, 6-8 Avenue Blaise Pascal, Cite Descartes F.77455 Marne –la-Vallee Cedex 2 France

Public Private Partnerships (PPP) have often been studied through the economics of contracts; the aim of this paper is to analyse them rather through the economics of services. The importance of client interface will be pointed out in relationship with the changes in project and in services governance in PPP, in France and in UK. Based on comparative research about PPP in French and UK hospitals, three main assumptions are argued. Firstly, PPPs, as complex, global and long-terms contracts, precipitate the passage from "construction" to "services". Beyond the differences in this evolution that we can observe in France and the UK, the question of client interface is of great importance in both countries. To analyse it, the economics of services are referred to rather than the economics of contracts. Secondly, in this context, the increasing difficulties the client faces when defining the performances in terms of output and outcome hypertrophies the role of benchmarking and the change of procurement process as a way to elaborate the judgement of effectiveness. This paper focuses on the experience of "competitive dialogue" in France and the UK to examine how this judgment of effectiveness in a long and complex contract lays on incremental and iterative process between the client and the providers, through more complex organisations in every side. It underlines how efficiency trends become more relational. Our third assumption is that the client interface stays very crucial in the post-contractual phase. But, while the economics of contracts insist on the question of information asymmetry for the client, the economics of services enlightens the strong interdependence between the provider and the client in the delivery of services. Therefore, it is argued that operating services by outcome mobilizes not only contracts but also conventions between the public client and the private provider and that effectiveness become more relational.

Keywords: client interface, economics of services, public private partnership.

INTRODUCTION

In most European countries, the development of Public Private Partnerships (PPP) has been accompanied by major upheavals in public commissions and considerable changes in project organisation. It is essential to qualify these changes, the forms they take and the issues they cover. The aim of this paper is to point out the importance of client interface in relationship to the changes in project and services governance in PPP in France and in UK. On the basis of comparative research about PPP in French and UK hospitals (Campagnac 2006), we will underline the place, role and characteristics of the "client interface" in the PPPs from three points of view.

[1] campagnac@enpc.fr

1. The first one relates to a theoretical point of view: it consists to clarify the status given to the "client interface" in our approach and the interest that we pay to the economics of services. The starting point is on our assumption that the PPPs, as complex, global and long-term contracts precipitate the passage from "construction" to services. We will refer here to the theory of services (Hill 1977, Gadrey 1996) and to its conceptual approach of services as the result of a co-production process between the beneficiary (here the public client) and the supplier (here the private consortium). The aim of this co-production is the transformation of a material or immaterial good belonging to the client.
2. The second one refers to the treatment of the client interface in the commissioning and to its consequences on the project's organisation. This second part will focus on the change in procurement. We will argue that, in the PPPs, the client interface has become the most strategic phase of the project. This is not only due to complexity and to uncertainty of the project but also to the conditions of its achievement from the point of view of economics of services. The increasing difficulty for the client to define the performances in terms of output and outcome is actually a characteristic of the economics of services. It encourages new offer strategy from the private consortia and militates for a complete change of the rules of game in the procurement and other criteria of judgment. For instance, the role of "benchmarking" appears as a way to elaborate the judgement of effectiveness, at different steps of the project. Through the examination of "competitive dialogue" in France and the procurement process to select the "preferred bidder" in Great Britain, we will focus on the incremental and iterative process between the client and the provider to elaborate this judgment. We will argue that effectiveness tends to become more collective and to depend on the links between the operations, between the individuals and the collective units along the line of clients specifications programming, design, build and operate, and often. So we will argue that a deep change in project governance is occurring that cannot be reduced only to the arrival of new actors in the process and their multi-rationality (investors , developers, FM operators and legal and financial advisers etc.) but which need to take in account the passage of vertical to horizontal coordination between different organisations and some lessons of cognitive sciences especially in the project design (Hatchuel 2002; Darses and Falzon 1996; Benghozi *et al*. 2002).
3. The third assumption refers to the post-contractual phase (between the public client and the facility management operator). Two main lessons can be pointed out from our research: (a) operating maintenance and services by outcome and inside a private consortium means very often a re-engineering of service; and (b) it is a very sensitive phase that could lead to misunderstanding between public and private partners. We will analyse how effectiveness in operating services by outcome mobilizes not only contracts but also conventions between the public and private actors, and how it redefines the competencies when effectiveness become more relational. A lot of PPP experiences show that many failures occur in the post-contractual phase because the dimension of "services" have not been taken in account in an appropriate way. Therefore, the post-contractual phase presupposes a long learning process between the public and private partners.

THE CLIENT INTERFACE IN PPP REFERRED TO THE ECONOMICS OF SERVICES

In the economic literature, PPPs have often been studied through the economics of contracts; we propose to analyse them here through the economics of services. We will now discuss the main differences between these two theories. The economics of services is different from the theory of transaction costs, because its assumption is based on the uncertainty about the product rather than uncertainty about the behaviour, like in the transaction costs theory. Transactions are seen as interactions productive of value and use value rather than costly frictions. The concept of "co-production of service" reflects the high uncertainty of the product.

Three main arguments militate in favour of the mobilisation of the economics of services in the case of PPPs:

- The identification of the field of application of the PPPs and the content of the activities, based on the distinction between service as process and service as result.
- The changes in terms of commission and their congruence with the "triangle of services activities", promoted by the theory.
- The redefinition of the efficiency approach in this kind of contract.

Field of application of PPPs and content of activities
No matter what specific contractual forms covered by PPP in the various countries – from the Private Finance Initiative (PFI) in UK, conceived in the early 1990s, to the "partnerships contracts" in France, launched in the 2000s – they all seem to present certain points in common, in particular those ones in breakdown with the traditional procurement :

Changes in the nature of the contract
In most cases, PPPs replace standard contracts based on separate assignments by a global contract covering the financing, design, construction, management and operation of public buildings and a proportion of the services that they provide. So a PPP contract is no more a sole construction contract but a construction plus a service contract, because it includes a more or less large part of services. Moreover, operating services is the support for public payments. The PPP is presented as a way for the administration and public authorities for getting new buildings and facilities, delivered and maintained by the private operators, and for funding them only through annual payments on many years.

Changed position and status of the public client or public sector party
The global contract is long term, paid for by public authorities and spread over time. The public sector party loses its status and function of contracting authority. Its mission is no longer to find the financing and organize the financial packaging, set out the construction programme, choose the designers, project managers and contractors, etc. Its position and function is transformed into that of a buyer which, within the framework of a *complex contract* spread over a *long period,* is called on to specify the functionalities expected from the building and services that it will place in the hands of a private consortium (cleaning, maintenance and operational services or services covering activities peripheral to public services).

Field of application
One of their main characteristics compared to the more classical concession or delegation of public services, is their field of application: the PPPs concern more the regalian public services (as Police, Justice, Defence etc.) and the most symbolic among the welfare state services (health and education, through hospitals and schools) rather than only infrastructure and public utilities, as before.

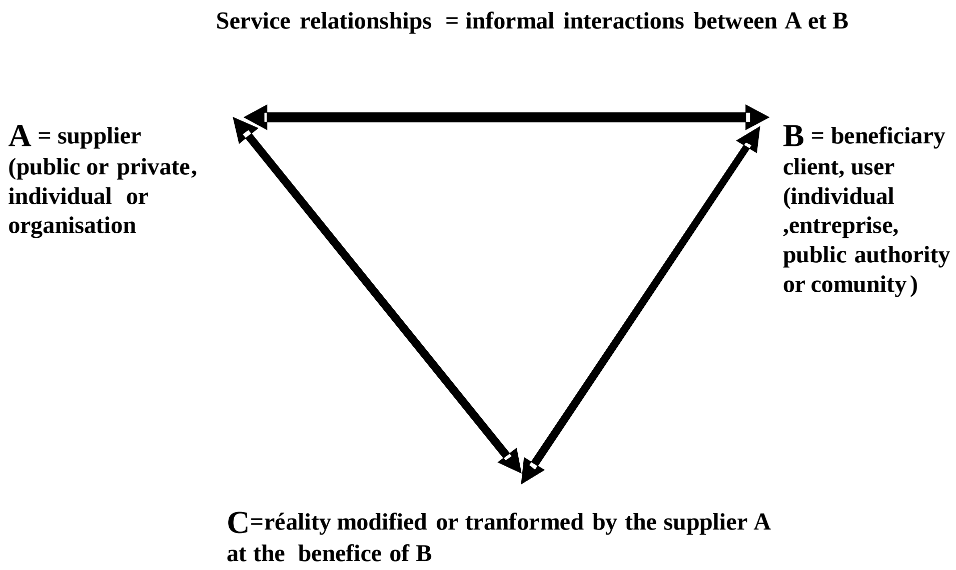
Changes in the public and private services borders and governance
The perimeter of the services activities included in the contract is quite decisive. The usual distinction is between “core services” and “non-core services”, for instance “clinical” and “non-clinical” services in the health sector. PPPs invite another distinction. Because they include construction, hard facilities management (related to the building operating and maintenance) and soft facilities management (related to the service to the person) , we would refer here to the distinction used by Curien (2002) between three main layers (infrastructure, service operating or intermediary services, and final service to the users). The redefinition of the frontiers between these three main layers is one of the main issues of the PPP. It is a complex one because it involves legal, political, social, economic and cognitive issues. Just let us keep the question of outsourcing can’t be put in the same terms for “public services” and commercial activities. (In this perspective we are interested by the distinction made by Nicinski (2001) and quoted by Villain-Courrier (2004) between “the relation of supplying a service” that could be publicly or privately managed and concerns the user in contact with the operator’s employees in a strictly commercial relationship and “ the relation of public service” that concerns the double exchange relationship between the members of the users’ community on one hand, and the users and public authority in charge to the good operating of service on the other hand. It is characterized by some derogatory dispositions.)

So, while the development of these new types of contracts in different European countries is generally linked to the imperatives of budgetary policies, limited spending and a reduction in public debt, we propose that they be considered from other points of view. Rather than simply limited to being budgetary tools, the PFI/PPP are vectors that have resulted in upheavals in public orders and project organizations structures. They also accompany the reform of “modernization” of public services in France and in UK .In other words, PPPs are far from being insignificant forms of contracts. They simultaneously translate a change in the way that orders are organized on a public policy level and a change in the management of the services associated with the concerned buildings. It could be said that there is a change in the “governance” of services.

Changes in terms of commission: The “triangle of services activities”
Theoretically, these contracts are supposed to be not a delegation but a *partnership,* laying on the idea of mutual advantages between the public and the private actors. These mutual advantages are often presented in terms of risk sharing for the private investors and referred to the financial rationale for the private partner and to the budgetary constraint, for the public client; Or in terms of service improvement and referred to the assumptions of greater management capacities by the private sector. None of these approaches could be satisfying; they need to be checked, proved and demonstrated.

That’s why we propose to focus on PPP not only as service activity but also as service relationship.

Gadrey (2003) insists on the three poles of a service relationship when he defined it the characteristics of a service activity: “ a service activity is an operation, whose the aim is a transformation of the state of an activity C , owned or used by a consumer B (or client or user) , realised by a supplier A on the demand of B, and often in relationship with him, but the outcome is not the production of a good which can circulate economically independently of its support C”.



Source : Jean Gadrey, « socio économie des services », La découverte, 2003, p.19

Figure 1: The triangle of services activities

Redefinition of efficiency: outcome and service value

A second range of changes introduced by PPP concerns efficiency. In a service activity, the way to appreciate efficiency and to measure is quite different compared with an industrial production activity. It lays longer on the expected outcome than on the physical output. As in every contract by result or by targets, the object of the contract in PPPs is no more or not only tangible assets (the built infrastructure) but intangible assets (quality of maintenance, quality of delivered services). Different authors underlined the breakdown coming up with the industrial era when the most important thing was to sell goods with occasionally a free small service as a commercial argument; but the object of the transaction is now inversed: some companies sell the product at a very low price because they make profits on the long run service supply. Different authors insist too on the fact that in a service activity, it is the value that is very important and it can be appreciated in terms of direct product but in terms of indirect results. For instance, in a hospital, the service to a patient cannot be appreciated only by the cares that he or she receives, but by the real improvement of his or her health and by his or her recovery. So, the value service can be defined as the price that a client is ready to pay for the transformation that he or she judges positively (Gadrey and Zarifian 2002). It lays on a judgement about the service and its quality, and it supposes that this one succeed to be really delivered.

The situation for PPPs is more ambivalent because there is, of course, a part of tangible assets with the building construction, but the new situation is that the private partner sells to the public client a right to access to future value – maybe a share of the additional land rent – and the use of a range of services for long run. This movement is said changing the relationship to the assets: the right to use them is more important than their ownership and what is sold to the client is the permanent availability for use. This phenomenon goes with an extension of merchandising of every exchange. A real question is: what does the client buy through a service relationship? In fact, he or she can buy many things, from potentiality of gains in productivity (industrial partnership), to capacity to anticipate on the future, going through potentiality of more availability.

CO-PRODUCTION OF SERVICES AND CLIENT INTERFACE: TWO CASE STUDIES

The previous developments have put the accent on service relationship as result. This one will focus on the service relationship as process.

In this long run contract orientated to outcomes, where the transaction concerns some results to reach, the concept of co-production of the services is essential. In theory, co-production means an active attitude from the client-user: he or she has to inform the supplier and precise his or her demand as it goes along. The supplier has to adjust his or her proposal continuously. It means that the service relationship needs necessary time to construct it (contextualization, mutual adjustment, drafting of contract etc.) before technical dialogue and exchange. The role of appraisal and judgment of effectiveness become quite crucial in the process design, precisely because of the uncertainty about the "product".

What is the reality in PPPs? Firstly, it appears quite more complex because the client interface cannot be reduced to a simple interface between two individuals, but it mobilizes a great number of stakeholders on both the public and private sides, which offer a large diversity of design and appraisal criteria. For instance, in a PPP, the efficiency and effectiveness of service activities can be appreciated through various criteria such as industrial (efficiency and productivity), commercial (turns over and profit), civic (equity, contribution to common good) and financial ones (value created and risk sharing).

Secondly, it cannot be reduced to a "single colloquium" between the public client and the private consortium: in reality, the client's interface is mediated through a lot of rules, tools and calculation procedures that "instrument" the decision and could orientate it. Their role is not insignificant in the decision process.

Nevertheless, we argue that client interface tends to become more and more strategic for the success of PPP's and that through this "connection" the main issue is the co-production of services. That is why, whilst in a classical construction contract, the strategic interface for success is between design and construct, in PPPs as global and complex service contract, the strategic interface is the client interface (Campagnac 2001). We used to qualify this client interface as opening a "new service market", mobilizing cognitive and communicational changes, around the questions of complexity in decision making and uncertainty about the product.

But, in this process, it is very important to make the distinction between final service, i.e. public service, which is supposed to remain the core of the public client's activity, and the intermediary services (the different kind of facilities management), which are delegated to the private partner. The cases studies that we analysed in France and in UK through PPP in hospitals (Campagnac 2006) could illustrate each of these two points. Both concentrated on two hospital operations: a PPP/PFI operation in England (Case study A) and an emphyteutic hospital lease in France (Case study B). The two concerned operations are very different from one another in terms of size, cost and object. The case study A includes 155,000m^2 of new buildings + 109,000m^2 of existing buildings for a cost of £380 million, being €556 million; The case study B (a logistical platform for chemist and general services) concern a new building around 6,000m^2 of usable floor area at an estimated cost of €11 million. At the same time, they are relatively characteristic of PPP operations in both these countries. To understand the similarities and the differences, we compare these two operations on the basis of the interdependence resulting from the:

- *Politico-institutional and politico-legal context*: the challenge here is to link the advent of PPP in the hospital sector in both countries to health service reform modalities and changes in the rules governing public management in this sector.
- *Formal coordination procedures* instigated by the public client and the public regulation authorities, and *effective coordination and cooperation practices* of the concerned parties.
- *Contribution of the various concerned parties* to the development of the project, focussing on the interface between the concerned parties in the construction of the decision.

Client interface and complexity in decision making

The case study in the UK (Case Study A) is appropriated to illustrate the client interface face to the complexity in decision making. In the UK as in France, the development of PPPs takes place in a general context of reforms in public health system and in public management. However, the PPPs do not have the same outlines in both countries, partly because the nature of the problems met is not quite the same. Even if they face some similar challenges (budgetary and financial viability, societal evolutions, changes in models of healthcare, medical innovations etc.), they don't have the same inheritance. We can observe the differences between the national health system model, inherited from the Beveridge model on the one hand and the continental social insurance system inspired by the "Bismarck model on the other hand .The major problems for the first one are waiting lists and a lack of new construction over many years; the major problem for the second one is a very high level of expenses and increasing costs. But we can observe also the different aims of PPP in this sector in both countries.

Faced with these problems, the PFI in our case study A – one of the biggest launched in UK – combines a large hospital restructuring with a redevelopment of the buildings. It takes place in a context where the reallocation of healthcare supply between the NHS Hospital and Primary Care Trusts (PCTs), designed as a "mixed economy of care", is at the heart of the reform. In these conditions, the client interface illustrates the complexity in decision making, with a strong inter-dependence between the medical services programming (the health service process), the PFI financial process and the elaboration of commission brief. In this complex decision making process, the public client is in relationship with different public authorities with whom he or she has to negotiate at the local level (PCTs, Strategic Health Authority) or at the national one (Department of Health, PFU, Treasury etc.). He or she has to combine and manage different process: the Gateway process for *the strategic healthcare line*, the *Outline Business Case* and then the call to competition to private partners. Because of this complexity, the choice of the preferred bidder needed two years, from the "Prior Information Notice" (PIN) in July 2000 to the choice of Catalyst as preferred bidder in June 2002. The financial close was signed in December 2004. The main steps have been:

- Preliminary invitation to negotiate (PITN): from September to November 2000.
- Final invitation to negotiate (FITN) from April to November 2001.
- Best and final offer, from February to May 2002.

There were some interruptions betweens these steps due to the uncertainty in allocation of healthcares.

Compared with the French case studies, the decision making process has been also characterized by the importance of the question of risks sharing and risks management, going with the identification of services to externalize. In this case, the externalization was very large, including hard and soft facilities management, in logic of deconsolidation. If the whole process lays on many formal procedures, it supposes also a lot of negotiations between the public client, the PCTs and the local authorities, especially between the Outline Business Case and the Full Business case; the public client and the consortium. The client interface in this last aspect has been characterized by the mediation of a lot of private consultants, in order to speak a common language with the private consortium, but also in order to gather all the needed competences to discuss the project and select the preferred bidder according to different criteria. In the judgment to classify and select teams, those criteria have been the following ones: 35% for quality of Design and Build; 30% for services; 20% for legal set up; and 15% for financial.

The example of Case Study A shows that the co-production or co-design of the services are public-public (especially for the clinic services) as well as private –public (for the hard and soft FM), and follow different approaches according to each of them.

Client interface in "competitive dialogue": the change in the rules of game.
The increasing difficulties for the client to define the performances in terms of output and outcome – which is another characteristic of the services economy – militates for the client not only a global contract, but also a complete change in the rules of game of this procurement.

First of all, he or she has to justify the decision to use PPP or PFI as a contractual mode to realize the building and manage its facilities management, and for that he or she has to prove the different advantages brought by PPPs in comparison with the classical procurement. In France, those advantages concern mainly three questions: global cost or whole life cycle cost; risk sharing, results and achievements. In the UK, this previous justification is based on the public sector comparator and on the regime of best values. In fact, as many authors underline, this previous analyse hesitate between a real evaluation *ex ante* and a justification using fundamentally the same methods than the private ones coming from the experience of project financing; or still between a normative or a functional instrumentation to support the client decision.

Another change in the rules of game – which may be more relevant – concerns the client interface to propose a global project on the basis of targets to reach, specified by output and outcome. Through a case study in France, we could observe how Competitive Dialogue in France means changes as well in the design of assistance to the client (organizational and cognitive changes) as project design organization. The “Competitive Dialogue” is an original procedure from European Community Law (Directive 2004/18/EC). Its target is to optimize the public commissioning in the case of complex contracts. It introduces a long phase of discussion between the public client (and his or her representatives) and the different candidates in competition. The aim of this phase of discussions is to allow the elaboration of solutions in response to the expectations of the public client, expressed in terms of output and outcome, and also a benchmarking of the different solutions proposed by the candidates; one consequence of that is that the client’s brief henceforth is “blurred”. The schedule supposed to be clarified along a design process is characterized by three main stages:

- Principe Partenarial et Organisationnel (PPO) (*Organizational and partnership principle*);
- Proposition Prévisionnelle Sommaire (PPS) (*First projected proposal*);
- Offre Finale (OF) (*Final offer*).

The solution is supposed to be devised through a “dialogue” between the public client – with his or her assistants and different commissions – and the private consortium; at the same time, this “dialogue” has to be a competitive process that means that it has to stay quite confidential. Compared with the procedure of the “preferred bidder” the competitive dialogue is more strictly regulated and supervised. So, it needs new competencies on the public client’s side.

On the candidates’ side, it has also important impacts on the forms of cooperation inside the private partners’ teams. It was one of our conclusions of the case study in France (a hospital logistic platform in Case Study B). We had the opportunity to accompany one of the competitors’ teams during the competitive dialogue). The criteria to select the final bidder were a little different than in UK, with 15% for architectural and technical qualities, 25% for functional quality, 30% for financial quality and 30% for legal quality

We could observe different changes in comparison with a classical tender in construction market, especially these ones:

- The teams of the partner candidates are not compounded on the basis of a competitive selection but on the basis of a cooptation between the developer, the bank, the construction company, the architects and the facilities managers’ suppliers.
- Design of the global project is more collective and overall characterized by a cognitive synchronization, an iterative and loop approach, different situations of cooperation, from allocated design to co-design.
- With the multiplicity of targets in our case study – architectural quality, innovative design around the aim of high environmental quality, facilities quality for the users, increasing efficiency of industrial logistic process, optimizing the flux, but also increasing patrimonial value, economic competitiveness, financial profitability, mutualization of resources – we observed that the actors have to co-construct a common frame of reference.

> They spend a part of time to construct their internal agreements "around the table".

Therefore, we could say that this procedure – despite its limits – encourages an incremental and iterative process between the client and the provider, even if cultural gaps are strong between the public clients and private consortia. However, it also encourages, maybe more strongly, the internal cooperation inside the team. That is why we could argue that effectiveness tends to become more collective, and to depend on the links between the operations, between the individuals and the collective units along the line of clients specifications programming, design, Build and Operate, and often. In other words, we could speak of effectiveness linked with an "open cooperation" (Veltz 2005).

THE CRUCIAL ROLE OF CLIENT'S INTERFACE IN THE POST CONTRACTUAL PHASE: FROM CONTRACT TO CONVENTION

Whilst in most of the PPP contracts the stress is put on the construction risk, we would underline, based on our experience, the importance of service supply risk (mainly associated to the obligation of constant availability).

We could insist on two main points: the first one is that PPP with outsourcing of services means very often a re-engineering of services. This re-engineering takes different forms according that PPP is built in a greenfield or not. If it is applied to old buildings like for many hospitals in the UK, the re-engineering could be strong; the main dilemma in re-engineering process is once more, the multiplicity of targets and the different approaches that the private partners and the public client could have about effectiveness. For instance, it would be suicidal for the private supplier to think re-engineering only through the target of profitability, he or she has to take in to account many other criteria such as quality of services, efficiency of the team organization according to the performances indicators and contractual obligations, but also according to technological changes, new competencies required, training of employees and so on. A lot of facility managers discover the difficulty to assume both hard and soft facilities management properly in regard to their contractual commitments. The origins of these difficulties are numerous: for one part, they appear as a consequence of different rationalities between contractors and service suppliers and as the insufficient taking account of operating phase at the first stages of the project. But for another part, they come from the inexperience of private facility managers regarding the work in the public sector, in particular for all the works regarding the service to people. Most of the difficulties met are mainly relational difficulties, with the employees (overall in the first years before the agreement with the trade unions to transfer the employees of public sector to operate the maintenance and services), but also with the users (inexperience to manage the services in a public context).

The second point of our observation is that the post-contractual phase reveals the deep lack of contract fulfilment face to the nature of these difficulties. That means that the success of PPP in the post-contractual phase lay on the construction of convention, beyond the contract, between the public client and the private facility manager. Such a construction of conventions needs discussions, negotiations and common interpretation of the standards specification. So, a large communicational work is necessary to the success of the contract but we observed also that, very often, this agreement is easier if the facility managers or the SPV leader comes himself of herself from the public sector.

So one of the paradoxes of PPP could be that, launched to give to the public sector the benefits of the knowledge coming from private sector, their success would depend on the inverse process of giving the private sector the benefit of the knowledge of the public sector. The analysis of the professional trajectory and careers of PPP managers could be then decisive. But it is not exclusive of a discussion concerning the need of a crossed learning process between public and private partners.

CONCLUSION

In this paper, we argue that economics of services is very relevant to study the changes introduced by PPPs. To develop further this assumption, it is very important to get the appropriate *ex post* evaluation of the different PFI/PPP contracts. This kind of evaluation is more developed in UK than in France where the tradition of *ex post* evaluation is very weak. It has been developed especially around the notion of Value for Money (VFM). Different critics have been made to VFM. The VFM methodology has been questioned through different studies and researches concerning in particular PFI hospitals. A lot of them concluded either to the limits of VFM to evaluate really the user opinions about services and more generally all the soft project objectives, or the distortion that it introduces in the performance and measurement design (Edwards and Shaoul 2003; Edward *et al*. 2004; Pollock and Vickers 2002). Some efforts have been made afterwards to a comprehensive evaluation of outcomes compared with what was expected or to improve the procedures (for instance, HM Treasury 2003), but evaluation of such kind of contracts remains extraordinarily complex. More modestly, we have observed in most case studies analysed here and there, now or before, that the importance of co-production of services has been very often underestimated, especially, in the pre-contractual phase, with large consequences on the service operating . But it appears too that co-production of services tends to be better taken in account and it is seen, in any case, like a learning process.

REFERENCES

Campagnac, E (2001) La commande comme nouveau marché de services. *In*: A Bourdin (Ed.) *Projet Urbain, maîtrise d'ouvrage, commande*. Espaces et Sociétés n°105–106, N°2-l'Harmattan.

Campagnac, E (2006) *Les nouveaux contrats de partenariat public privé: un vecteur de transformation de la commande et des organisations de projet.* Rapport Plan Urbanisme Construction Architecture (forthcoming).

Benghozi, P J, Charue-Duboc F and Midler, C (Eds.) (2000) *Innovation Based Competition & Design Systems Dynamics*. Paris, L'Harmattan.

Curien, N (2000) *Economie des réseaux*. Paris: La Découverte.

Darses, F and Falzon, P (1996) La conception collective: une approche de l'ergonomie cognitive. *In:* G de Terssac and E Friedberg (Eds.) *Conception et cooperation*. Octares.

Edwards, P and Shaoul, J (2003) Partnerships: for better, for worse? *Accounting, Auditing and Accountability Journal*, **16**(3), 397–421

Edwards, P, Shaoul, J, Stafford, A and Arblaster, L (2004) *Evaluating the operation of PFI in roads and hospitals* The Association of Chartered Certified Accountants, Manchester Business School, University of Manchester, research report no. 84.

Gadrey, J (1996) *Services : la productivite en question*. Paris: Desclee de Brouwer.

Gadrey, J and Zarifian, Ph (2002) *L'émergence d'un modèle de service: enjeux et réalité*. Editions Liaisons.

Gadrey, J (2003) *Socio-economie des services*. Paris: La Decouverte.

Hatchuel, A, Le Masson P and Weil, B (2002) De la gestion des connaissances aux organisations orientées conception. *Revue Internationale des Sciences Sociales de l'UNESCO*, **171**, 29–42.

Heath, C and Luff, P (1994) Activité distribuée et organisation de l'interaction. *Sociologie du Travail*, **XXXVI**(4), 523–45.

Hill, P (1977) On good and services. *The Review of Income and Wealth* , **4**, 315–38.

HM Treasury (2003a) *Appraisal and Evaluation in Central Government: The Green Book*. London: The Stationery Office.

HM Treasury (2003b) *PFI: Meeting the Investment Challenge*. London: The Stationery Office.

Palier, B (2004) *La reforme des systemes de sante*. Paris: Presses Universitaires de France.

Pollock, A and Vickers, V (2002) Private Finance and Value for Money, in NHS Hospitals: A policy in search of a rationale? *British Medical Journal*, **324**, 1205–8.

Veltz, P (2005) L'efficacité par la cooperation ouverte. *In:* G Minguet and C Thuderoz (Eds.) *Travail, entreprise et societe*. Paris: Presses Universitaires de France.

A STUDY OF HOMEBUILDERS' COST MANAGEMENT ON SMALL-SCALE PROJECTS IN JAPAN

Kazuyoshi Endo[1] and Toru Onodera[2]

[1]Architecture, Kogakuin University, 1-24-2 Nishishinjuku, Shinjyuku, Tokyo 163-8677, Japan
[2]JMA Consultants Inc., Tokyo, Japan

The source of construction firm's business profit is nothing but the balance between his contract price and the amount of total cost he invests. The contents of such a cost management activity are the core of construction firm management. This study, with its focus on the small-scale works by homebuilders in Japan and by analysing their hitherto untouched internal documents, aims to clarify the actual cost behaviour and methods of their cost management activities. The results of this study indicate that the homebuilders' practical profit-making from miscellaneous expenses largely depends on the flexible use of permanently hired carpenters as well as the builder's effort to conduct effective procurement.

Keywords: homebuilders, cost management, working budget, managing construction firm.

THE BACKGROUND AND PURPOSE OF STUDY

Under any building contract system in Japan, the builder must provide the ordered building as specified in the design drawings with the contracted price. The contract price is determined by the result of not only the price negotiation with the owner but also of winning the competition with other builders. This means that such a result would not necessarily be what the builder had wished in the beginning.

It is evident that the source of builder's business profit is nothing but the balance between his contract price and the amount of total cost he invests. In order to create such a positive balance, the builder rearranges the project's budget within the amount of the proposed contract price and executes a cost management activity.

The contents of such a cost management activity is nothing but the core of construction firm management, under which the builder does not need to disclose specific processes and results of individual projects, and the owner principally cannot request such disclosure by the builder in Japanese contract conditions. Therefore, the accumulation of the builder's work experience is stored inside his firm, and there have been little efforts made toward objectively examining what has been written and what has been done.

This study, with its focus on small-scale works by homebuilders and by analysing their hitherto untouched internal data, aims at clarifying the actual facts and methods of their cost management activities to compile a basic resource of related information that would facilitate better understanding of homebuilders' cost behaviour and management of construction firms' business.

[1] endo@sin.cc.kogakuin.ac.jp

THE OBJECTIVES OF THE STUDY AND METHODS USED

This study analysed traditional wooden detached houses, which held about 25% of the Japanese annual housing construction number of houses. The houses analysed in this paper are still the main system of housing in Japan. The scales of the homebuilder who supplied it were various, but intended for comparatively small homebuilders in this study.

This study took up, for comparative purposes, three typical homebuilders as locally accessible construction firms, as shown in Table 1. In selecting the three firms, consideration was extended to their in-company status of developing and storing related data and documents. Here is an outline description of the three homebuilders:

- Firm A: a local firm specializing in custom-made wooden houses. Fabrication of framework materials is mostly done in-house, with some partly depending on procurement of pre-cut materials. As they largely depend on manual carpentry, the main workforce consists of regularly hired carpenters.
- Firm B: a firm specializing in house and store interior work. It is also experienced in serving as a subcontractor for certain general constructors and in manufacturing furniture. It operates its own fabrication unit, where carpenters are hired as regular personnel, who are multi-skilled in line with the firm’s main business line.
- Firm C: another local firm specializing in custom-made wooden houses. It has also participated in projects of building condominiums and hospitals. With no in-house fabrication facility, subcontractors who work almost on a full-time basis for this firm provide part of its carpentry work. Major materials are fabricated by hand. In addition, to maintain an antenna-shop, the firm displays a “model house” at a major model-home park. This strategy leads to a relatively higher probability for the firm to face some major housing makers as well as other rival builders.

The authors have been able to obtain needed cost management data in a total of 27 itemized data from the above three homebuilders. With each of the selected 27 projects, the collected data such as detailed cost estimates presented to the client, working budget documents, account books for specific projects, and cost estimates submitted by the vendors were entered into spreadsheets so as to better analyse the actual composition of and changing trends in contract costs and prices.

Table 1: Homebuilders selected for the study

Firm	Location	Amount of annual sales (million yen)	Annual no. of new homes built	No. of all workers (regular staff incl.)	Major line of business
A	Tokyo Metropolis Suburban	220	7	12(8)	Wooden house, custom-built
B	Tohoku pref. govt. city	150	1	9(6)	Refurbishment
C	Shikoku pref. govt. city	800	20	40(12)	Wooden house, custom-built

COST DATA RELATING TO SMALL-SCALE CONSTRUCTION PROJECTS STRUCTURE OF THE DOCUMENT

Here are descriptions of each of the four cost-related documents.

Detailed cost estimates presented to the client
According to the commonly used contract clause, the contracted builder is to submit detailed cost estimates as a price list for approval by the client. Actually, however, the commonly used practice is that such a breakdown is to be shown by the builder even during the pre-contact negotiations as evidence of his contract pricing intention. Thus, every detail of the cost information as shown in this paper should represent the breakdown, which is finally attached to the contract resulting from pre-contract negotiations.

Working budget document
This is an in-house document for each homebuilder, prepared for securing the eventual profit from the project. There are different motives for developing such budget documents, as shown below:

- The budget document is prepared prior to the cost estimates being presented to the client and reflects the builder's concept of cost management and/or some technical characteristics of the project itself.
- The cost estimates for the client and the working budget document are consolidated by using suitable software etc.
- The working budget document is prepared independently from the cost estimates for the client.

Account book for specific project
This document represents the aggregate on the part of a homebuilder of the actual generated labour costs, materials costs and payments to related suppliers.

It is to be used for managing ongoing costs and for verifying the generated project costs.

Cost estimates collected from vendors
This is a batch of cost estimates presented by the suppliers and/or vendors on which the date of estimation made and the time limit of validity must be shown.

The builders will select qualified vendors by checking against this document and may refer to or quote from the document when they prepare detailed cost estimates for the client. Thus, the date of preparation of this document may vary widely from a date prior to that of preparing such documents as detailed cost estimates for the client and working budget statements to a later date after starting the project work.

FACTUAL ASPECTS OF COST ESTIMATION ON SMALL-SCALE BUILDING PROJECTS

Ratios of miscellaneous expenses at each phase of the firm's cost management
Our hearings made us believe that smaller homebuilders like the three firms would have to set an optimum ratio of miscellaneous expenses including profit at a level of 20–30%.

Percentage figures in Table 2 represent ratios of miscellaneous expenses for each of the detailed cost estimates, working budget statements and account books for specific projects, respectively.

While the average ratio of miscellaneous expenses throughout the 27 projects by the selected three homebuilders is 7.2%, it can be observed from the table that 17.5% is secured for the working budget and 22.4% for the actual payment in the account book. Through the listening sessions, it has become clear that negotiating clients may pick up miscellaneous expenses as a target for a discount subject, and that figures in terms of miscellaneous expenses would serve as a disadvantage in competing with other contractors. Because of this situation, the usual practice to avoid such disadvantages is for the contractor not to specify the real amount of essential miscellaneous expenses on their proposals in an effort to “downsize” this cost account.

Table 2: Percentage variation of the ratio of miscellaneous expenses at each phase of the contract activities

Firm	Detail cost estimates presented to the client				Working budget statements				Account book for specific project			
	Simple average %	Max. value %	Min. value %	Standard deviation %	Simple average %	Max. Value %	Min. value %	Standard deviation %	Simple average %	Max. value %	Min. value %	Standard deviation %
A	9.4	14.7	5.4	2.7	21.7	28.2	9.5	6.1	22.5	27.7	19.1	3.5
B	7.4	14.3	0.0	4.1				*	24.5	39.9	5.0	9.1
C	1.8	2.1	1.5	0.2	9.0	18.4	-4.6	9.9	13.5	18.7	10.1	3.5
All	7.2	14.7	0.0	-	17.5	28.2	-4.6	-	22.4	39.9	5.0	-

*Within Firm B, no records as working budget statements are filed because the field foreman undertakes the planning of the working budget by himself

The generality of the data in Table 2, however, requires special attention because the three homebuilders selected for this study do well in preparing the related costing data as well as in maintaining good filing of such data. In addition, it seems that the density of their cost management activities is substantial.

PROJECT BY PROJECT ANALYSIS OF THE STUDY DATA

This section is a report of the analysis of one project each from the three selected homebuilders, from which the characteristics of its cost management programme seemed to be relatively clear. In this article, we analyse it from the limitation of pages about three typical projects.

Firstly, some explanations about the terms used in Table 3 and elsewhere: [Plus-minus ratio] means increase/decrease of monetary value on each line item, and [Shared ratio by type of work] is the shared ratio by each account against the total figures. It should be noted that collective calculation was made on such “combined” works as undertaken by the same suppliers or vendors.

Result of analysis of Project A6 (Firm A)

Project A6 built by Firm A is a conventional detached house with a design build contract. Cost estimates presented to the client were prepared in June 2004. Its contract price was 20-million yen or unit price per square metre was 214,000 yen (including consumer tax). This firm has rich experiences in building this type of houses. The contract price includes design fee, which represents 3.0% of the total price.

The detailed cost estimates presented to the client were prepared based on the detailed calculation of cost data. Cost accounts were so arranged after what the respective suppliers had classified in their quotations. The working budget document largely follows the same pattern as in the respective cost estimate documents in the detailed cost estimates, working budget statements and account books for specific projects.

Table 3: A comparative analysis of ratios distributed according to subcontracted works for detailed cost estimates, working budget statements and account books for specific projects (for Project A6)

Type of subcontracted work	Cost breakdown in the					
	Detailed cost estimates (Col. 1)		Working budget (Col. 2)		Account books for specific projects (Col. 3)	
	Yen	%	Yen	%	Yen	%
Demolition work	1,085,763	5.4	1,018,584	5.1	1,016,400	5.1
Temporary set-up work	1,125,993	5.6	428,892	2.1	336,554	1.7
Foundation work	1,556,946	7.8	1,276,360	6.4	1,066,800	5.3
Tile work	79,800	0.4	72,115	0.4	178,786	0.9
Carpentry	6,042,826	30.2	5,076,414	25.4	5,490,344	27.5
Material cost	3,126,587	15.6	2,563,692	12.8	2,634,692	13.2
Labour cost	2,159,189	10.8	1,885,874	9.4	2,139,374	10.7
Order with another contractors	757,050	3.8	626,850	3.1	716,278	3.6
Roofing work	902,423	4.5	731,914	3.7	940,054	4.7
Metal work	412,154	2.1	336,966	1.7		
Plaster work	51,440	0.3	41,960	0.2	40,000	0.2
Wooden doors and windows installations	674,541	3.4	545,832	2.7	1,494,192	7.5
Steel doors and windows installations	797,948	4.0	649,016	3.2		
Painting work	192,654	1.0	155,163	0.8	140,000	0.7
Interior work	579,355	2.9	479,664	2.4	460,823	4.7
Miscellaneous work	1,909,808	9.5	1,564,788	7.8	3,254,562	16.3
Electrical installations	766,647	3.8	655,599	3.3		
Plumbing work	1,564,370	7.8	1,375,029	6.9		
Design fee	592,099	3.0	408,450	2.0	161,400	0.8
Miscellaneous expenses (including profit)	1,665,234	8.3	5,183,254	25.9	5,420,084	27.1
Total	20,000,000	100.0	20,000,000	100.0	20,000,000	100.0

Type of subcontracted work	Cost plus/minus on the						
	Working budget against the detailed cost estimates (Col. 4)			Account books for specific projects against the working budget (Col. 5)		Account books for specific projects against detailed cost estimates (Col. 6)	
	Yen	+/- %	Share by type of work %	Yen	+/- %	Yen	+/- %
Demolition work	-67,179	-6.2	1.9	-2,184	-0.2	-69,363	-6.4
Temporary set-up work	-697,100	-61.9	19.8	-92,338	-21.5	-789,439	-70.1
Foundation work	-280,586	-18.0	8.0	209,560	-16.4	-490,146	-31.5
Tile work	-7,685	-9.6	0.2	106,671	147.9	98,986	124.0
Carpentry	-966,412	-16.0	27.5	413,930	8.2	-552,482	-9.1
Material cost	-562,896	-18.0	16.0	71,000	2.8	-491,895	-15.7
Labour cost	-273,315	-12.7	7.8	253,501	13.4	-19,815	-0.9
Order with another contractors	-130,200	-17.2	3.7	89,428	14.3	-40,772	-5.4
Roofing work	-170,508	-18.9	4.8	-128,826	-12.1	-374,523	-28.5
Metal work	-75,188	-18.2	2.1				
Plaster work	-9,479	-18.4	0.3	-1,960	-4.7	-11,440	-22.2
Wooden doors and windows installations	-128,709	-19.1	3.7	299,345	25.1	21,704	1.5
Steel doors and windows installations	-148,932	-18.7	4.2				
Painting work	-37,491	-19.5	1.1	-15,163	-9.8	-52,654	-27.3
Interior work	-99,961	-17.2	2.8	-18,841	-3.9	-118,532	-20.5
Miscellaneous work	-345,021	-18.1	9.8	-340,853	-9.5	-986,263	-23.3
Electrical installations	-111.048	-14.5	3.2				
Plumbing work	-189,341	-12.1	5.4				
Design fee	-183,649	-31.0	5.2	-247,050	-60.5	-430,699	-72.7
Miscellaneous expense (including profit)	3,518,020	211.3	-	236,830	4.6	3,754,850	225.5

Table 3 represents detailed cost-estimating figures as spread in the detailed cost estimates, working budget statements and account books for specific projects, respectively. Analysis by each of these phases is discussed below.

Comparison between the cost estimates presented to the client and the working budget statements
The ratio of the miscellaneous expenses in the detailed cost estimates does not exceed 8.3%. Among all elements, the largest ratio is 30.2% for carpentry, half of which is 15.6% for cost of materials.

All cost accounts on the working budget documents are shown with lower listed values. The ratios of such reduction are particularly larger in the temporary work accounts. This may be due to such builders' on-the-spot ideas as (1) plans to have the lease costs (as included in the detailed cost estimates for the clients) to be replaced by their in-house inventory stock, and (2) use of regular carpenter-employees, etc. Most other cost accounts are seen to be listed as somewhere over 10% discounts.

According to the project-level breakdown of cost estimates on Table 3, ratios for carpentry (with a substantial share in the contract price) are even higher than the temporary work ratio (particularly evident in the material cost accounts with 16.0%). These increased ratios resulted in the remarkable jump in the miscellaneous expenses boxes on Table 3 from 8.3% on column 1 to 25.9% on column 2.

Comparison between the working budget statements and the account books for specific projects
The next analysis was to compare the data recorded on the working budget against the actual paid amounts in the account books for specific projects. It can be noted that the data for carpentry and some others on fieldwork ledger (Column 4) resulted in larger figures than working budget (Column 3). The listening sessions in this regard clarified some reasons such as: (1) overlooking of data; (2) incorrect forecasting; and (3) debit/credit adjustments with concerned suppliers, etc. From a wider perspective, however, amount of actual spending is seen staying within the limit of the working budget, and such excess payments on the individual work accounts are embraced in the total picture. Thus, the high ratio of the miscellaneous expenses at 27.1% (even compared to Column 3) can stay on Column 4.

Comparison between the detailed cost estimates and the fieldwork ledger
Here, reduction in ratios is remarkable in both the temporary work and design fee. While the reason for such reduction in the temporary work is pointed out above, the reduced ratio for the design fee is due to the builder himself who could replace the design work and not pay the intended design agent since he is a Certified Architect under the Japanese law. The ratios of tile work and the furniture work indicate that the actual payments exceeded the initial cost estimates. Thus, the necessary level of the miscellaneous expenses ratio is secured.

Result of analysis of Project B2 (Firm B)
Project B2 was a house-refurbishment project under Firm B's Design-Build with a total contract price at 4,516,350 yen. Firm B, too, has rich experiences in this type of projects. Usually, the refurbishment project is liable to the existing conditions of the contracted house, and therefore many cases have had to conclude the contract even before they can confirm the scope of contract work and other details.

Firm B reflected considerable differences between the figures in the detailed cost estimates and the data on the working ledgers. Nevertheless, it is usual that the initial contract price tends to remain unchanged unless otherwise necessitated for greater reasons. This means that cost management of these refurbishment projects has to face such restraining situations.

Comparative analysis for Firm B was made only between the Cost estimates for the client and the working ledger because no other formal documents are filed as the field workers executed the working budget planning on the spot.

Comparison between the cost estimates presented to the client and the working budget statements
Table 4 shows the results of comparing the detailed cost estimates with the actual paid figures of the account books for specific projects. As for the actual payments, the majority of project types turned out to be widely reduced, and the carpentry costs including carpenters' labour costs were found to have increased. This was the result of the expanded use of the permanently employed carpenters to cover other types of work wherever possible.

Table 4: Comparison of the detailed cost estimates and the account books for specific projects (for B2 project)

Type of subcontracted work	Cost breakdown in the					
	Detail cost estimates for the client		Working budget		Account book for specific project	
	Yen	%	Yen	%	Yen	+/- %
Temporary set-up work	262,605	5.8	0	0.0	-262,605	-100.0
Demolition work	189,000	4.2	0	0.0	-189,000	-100.0
Carpentry	2,695,159	59.7	2,970,634	65.8	275,475	10.2
Steel doors and windows installations						
Roofing work	301,980	6.7	262,500	5.8	-39,480	-13.1
Wooden doors and windows installations	64,050	1.4	33,180	0.7	-30,870	-48.2
Painting work	119,910	2.7	21,000	0.5	-98,910	-82.5
Interior work	189,735	4.2	189,735	4.2	0	0.0
Electrical installations	153,300	3.4	0	0.0	-153,300	-100.0
Design fee	157,500	3.5	0	0.0	-157,500	-100.0
Special discount	-36,889	-0.8	0	0.0	36,889	-
Miscellaneous expenses (including profit)	420,000	9.3	1,039,301	23.0	619,301	147.5
Total	4,516,350	100.0	4,516,350	100.0		

Particularly, a 100% reduction is seen in the temporary set-up work, demolition work, electric installations and design fee. There are some varied reasons for this: cost of temporary set-up work and demolition work were either undertaken by the firm's permanent-hire carpenters or were included in other types of work undertaken by the subcontractors, thus not requiring any payments for that matter. While it was not made clear why the cost of electrical installation work was reduced, it could have resulted from some account-offsetting transactions dealing with some past debit/credit records. Then, the design fee was absorbed into miscellaneous expenses because the work itself was done within Firm B. Thus, the overall cost reduction ratio went up from 9.3% for the detailed cost estimates to 23.0% over for the account books for specific projects.

Result of analysis of Project C3 (Firm C)
This is a private house as Design-Built by Firm C in 2004. A conventional wood-house building method was used. They adopted the standard specification for its model house. The contract price was 25-million yen at a square metre unit price of 170,000 yen. They offered 10.4% discount in the detailed cost estimates.

Table 5: A comparative analysis of ratios for the detailed cost estimates, the working budget and the account books for specific projects (for Project C3)

Type of subcontracted work	**Cost breakdown in the**					
	Detail cost estimates (Col. 2)		**Working budget (Col. 3)**		**Field work ledger (Col. 4)**	
	Yen	**%**	**Yen**	**%**	**Yen**	**%**
Temporary set-up work	996,610	4.0	393,200	1.6	243,057	1.0
Foundation work	1,247,316	5.0	1,020,000	4.1	919,400	3.7
Water-proofing work	304,508	1.2	250,000	1.0	140,000	0.6
Masonry	369,600	1.5	298,000	1.2	165,500	0.7
Carpentry	12,048,960	48.2	11,047,000	44.2	10,449,302	41.8
Material cost	8,415,960	33.7	8,002,000	32.0	7,330,602	29.3
Labour cost	3,633,000	14.5	3,000,000	12.0	3,060,000	12.2
Order with another contractors	0	0.0	45,000	0.2	58,700	0.2
Metal work	485,557	1.9	428,000	1.7	378,000	1.5
Roofing work	1,041,865	4.2	850,000	3.4	780,000	3.1
Plaster work	911,048	3.6	350,000	1.4	410,000	1.6
Wooden doors and windows installations	1,502,183	6.0	270,000	1.1	260,000	1.0
Steel doors and windows installations	1,844,430	7.4	1,520,000	6.1	1,200,000	4.8
Painting work	437,740	1.8	740,000	3.0	650,000	2.6
Interior work	693,551	2.8	484,000	1.9	460,000	1.8
Miscellaneous work	2,161,320	8.6	1,504,000	6.0	3,086,800	12.3
Electrical installations	1,136,415	4.5	980,000	3.9	785,000	3.1
Plumbing work	1,673,616	6.7	1,130,000	4.5	1,003,500	4.0
Design Fee	270,900	1.1	416,000	1.7	416,000	1.7
Discount	-2,600,218	-10.4	0	0.0	0	0.0
Miscellaneous expenses (including profit)	474,600	1.9	3,319,800	13.3	3,653,441	14.6
Total	25,000,000	100.0	25,000,000	100.0	25,000,000	100.0

Type of subcontracted work	**Cost plus/minus on the**					
	Working budget against the detailed cost estimates (Col. 5)		**Account books for specific projects against the working budget (Col. 6)**		**Account books for specific projects against the detailed cost estimates (Col. 7)**	
	Yen	**+/- %**	**Yen**	**+/- %**	**Yen**	**+/- %**
Temporary set-up work	-603,410	-60.5	-150,143	-38.2	-753,553	-75.6
Foundation work	-227,316	-18.2	-100,600	-9.9	-327,916	-26.3
Water-proofing work	-54,508	-17.9	-110,000	-44.0	-164,508	-54.0
Masonry	-71,600	-19.4	-132,500	-44.5	-204,100	-55.2
Carpentry	-1,001,960	-8.3	-597,698	-5.4	-1,599,658	-13.3
Material cost	-413,960	-4.9	-671,398	-8.4	-1,085,358	-12.9
Labour cost	-633,000	-17.4	60,000	2.0	-573,000	-15.8
Order with another contractors	45,000	-	13,700	30.4	58,700	-
Metal work	-57,557	-11.9	-50,000	-11.7	-107,557	-22.2
Roofing work	-191,865	-18.4	-70,000	-8.2	-261,865	-25.1
Plaster work	-561,048	-61.6	60,000	17.1	-501,048	-55.0
Wooden doors and windows installations	-1,232,183	-82.0	-10,000	-3.7	-1,242,183	-82.7
Steel doors and windows installations	-324,430	-17.6	-320,000	-21.1	-644,430	-34.9
Painting work	302,260	69.1	-90,000	-12.2	212,260	48.5
Interior work	-209,551	-30.2	-24,000	-5.0	-233,551	-33.7
Miscellaneous work	-657,320	-30.4	1,582,800	105.2	925,480	42.8
Electrical installations	-156,415	-13.8	-195,000	-19.9	-351,415	-30.9
Plumbing work	-543,616	-32.5	-126,500	-11.2	-670,116	-40.0
Design fee	145,100	53.6	0	0.0	145,100	53.6
Discount	2,600,218	-	-	-	2,600,218	-
Miscellaneous expenses (including profit)	2,845,200	599.5	333,641	10.1	3,178,841	669.8

Comparison between the cost estimates and the working budget statements
The ratio of the miscellaneous expenses in the detailed cost estimates is notably low at 1.9%, while the relative percentage of carpentry compared with the case of Project A6 is pretty high at 48.2%.

Comparison of the detailed cost estimates with the working budget shows figures that are widely reduced throughout all types except the painting work. In terms of money size, a reduction of over 1-million yen is seen for carpentry and wooden doors and windows installations. Reduction ratios of 30% and over are also seen in the temporary set-up work, plaster work, interior work, and plumbing work.

Thus, the above situation led to a large 13.3% increase in the ratio of the miscellaneous expenses because of the reduced price in the working budget exceeding the amount of price discount on the detailed cost estimates document.

Comparison between the detailed cost estimates and the account books for specific projects
As shown in Column 6 of Table 5, the only increase in cost was some 1,260,000 yen on the painting work, miscellaneous work and the design fee, and all other types of work realized more than a 10% reduction, particularly with larger percentages for the temporary set-up work (75.6%), water-proofing work (54.0%), masonry (55.2%) and wooden doors and windows installations (82.7%).

Summary of the project analysis
The analysis in this study confirms the fact that the usual practice on the part of these homebuilders is to intentionally split what is supposed to be handled as miscellaneous expenses into other types of work so that the miscellaneous expenses on record would appear to be low on the detailed cost estimates.

In the process of developing the budget, homebuilders have to be sure at first of a required amount of miscellaneous expenses, then have the budget allotted to each and all types of work, so as to be able to ensure the actual payments don't exceed the set limitations. It should be noted that in this process the extent of builder's compliance to the figures in the detailed cost estimates would depend on how well the entire project is being managed. Thus, there would be some discontinuing portions to be found between the detailed cost estimates data and the data of the working budget and other ensuing phases.

One of the factors that would enable the builders to realize the above processes is the builder's effort to come up with some "break-through contrivances" within the scope of his contract. For instance, there were cases where what would have been given to subcontractors on minor portions of small-scale projects were actually taken care of by in-house carpenters. This should enable the homebuilder to (1) save some expenses meant for subcontractors and (2) enhance the project's productivity through the use of in-house carpenters who would otherwise have been left on an idle-time situation. This is an example of homebuilders' planning flexibility, realized by permanently employing their own carpenters.

The second factor seems to be that many detailed cost documents directly use the listed prices or catalogue prices of necessary parts, equipment and supplies to be procured, thus creating balances from the actual procurement payments based on the actual selling prices. This status is apparent in handling the miscellaneous expenses on the part of homebuilders. Here again, the result of such saving efforts could depend on how well the homebuilders would pursue their own procurement actions and how good their "break-through contrivances" were.

However, if such "in-house contrivances" on the part of homebuilders can be empirically foreseen, we should then be able to point out some "fictional characteristics" in their detailed cost estimation documents. Thus, the owners may embrace some feeling of opacity in reviewing construction cost data as presented to them in our observations.

GENERAL CONCLUSION OF THE STUDY

In this paper, the actual cost data on the part of private homebuilders was analysed and the hitherto unknown situation surrounding their cost management methodologies was disclosed.

We can now say that homebuilders' cost management processes are rather amorphous (not uniform) and that considerable variances are seen depending on individual company practices and policies, specific conditions existing for individual projects and works. It was confirmed from not only the analysis of the document but also interviews to the managers. Much of their management was based on experience.

The results of this study, however, indicate that the homebuilders' practical profit-making from miscellaneous expenses largely depends on the flexible use of permanently hired carpenters as well as the builder's effort to conduct effective procurement. With the actual situation as observed above, it is apparent that homebuilders, in dealing with miscellaneous expenses, are now facing some difficulties or issues.

It is becoming difficult for homebuilders to keep hiring in-house carpenters due to several factors, such as wider use of pre-cut materials in the framework process, increased use of metal hardware, fitting works and interior works (which were usually taken care of by carpenters) being replaced with the purchased parts and other materials, etc. – all of which are shrinking the carpenters' sphere of work. Also making their status more difficult is the imminent possibility of the aging of skilled workers and of their mass retirement. Although it was not observed in this study, we know that some comparatively large-scale homebuilders keep overheads low by sending carpenter construction out to the subcontractor cheaply.

As to the need for workers' contrivance in the procurement process, its profit-squeezing flexibility is being pressed under such conditions as increased versatility of material distribution channels, price information is becoming more easily obtainable on the part of owners, etc.

Based on the result of the study, the authors intend to extend the study on finding a new style of the small-scale production in Japanese housing market, and also examining the possibility of a new business model.

REFERENCES

Kazuyoshi Endo and Toru Onodera (2005) By analysis of homebuilder's cost data. *Seasonal Magazine of Research Institute on Building Cost*, 27–32.

Toru Onodera and Kazuyoshi Endo (2006) Study on the cost management of small scale building works by homebuilders. *Journal of Architecture, Planning and Environmental Engineering, AIJ*, **610**, 147–52.

USING KNOWLEDGE OF THE BUSINESS CYCLE TO FORECAST BUILDING COSTS

Johan Snyman[1]

Medium-term Forecasting Associates, Building Economists, P O Box 7119, Stellenbosch, 7599, South Africa

Quantity surveyors in South Africa find forecasts of building costs useful when estimating. Builders' input costs comprise labour, materials, plant and fuel. Tender prices include these cost items plus the profit margins of building contractors. It is known that the profit margins of building contractors fluctuate over the course of the business cycle. This is why it is important, when forecasting building costs, to first determine the expected course of the business cycle. Experience shows that building contractors widen their profit margins in the upswing phases of the business cycle and shrink them during building recessions. This is one of the main reasons why tender prices fluctuate. Several other factors influence tender prices, *inter alia,* changes in input costs, productivity changes due to bottlenecks in the supplies of labour and materials, fluctuations in the degree of competition in tendering and the availability of work on hand. Knowledge of the cyclical features and trends in these cyclical economic indicators are useful when making informed forecasts of building costs, especially when they are integrated in a structured way.

Keywords: building cost, estimating, forecasting, price, profitability.

INTRODUCTION

Different people understand different things about building costs. This is due partly to the fact that all humans interpret what they see or hear in terms of their own experience and their own interests. A police officer on the beat is perceived as a threat by a burglar, but as an angel by the person being hotly pursued by muggers. It is important, therefore, to explain exactly what building costs mean in the context of this paper. Lay people often use the term building costs in a generic sense. Sometimes they speak of it as being building contractors' input costs. Other times they mean tender prices, i.e. builders' output prices. In this paper, a distinction is made between input costs and tender prices. Builders' input costs comprise labour, materials, plant and fuel. Tender prices include these cost items plus the profit margins of building contractors. It is known that profit margins of contractors fluctuate over the course of the business cycle. Other factors contributing to fluctuating tender prices include, *inter alia*, movements in wage rates and building materials prices, bottlenecks in the supplies of labour and materials, together with fluctuations in the productivity of labour and management. It is shown that fluctuations in the business cycle contribute to fluctuations in builders' input costs and tender prices. This interaction is at the heart of the dynamics of price formation in the South African building industry. The objective of this research is to promote a better understanding of these concepts and to improve forecasting in this particular field of economics.

[1] mfa@iafrica.com

THE BUSINESS CYCLE

The business cycle has four distinct phases: the upswing or recovery phase, the peak, the downswing phase and the trough. Business cycles are said to be recurring, but not periodic (i.e. not perfectly regular). A distinction is often made between classical business cycles and growth cycles. When gross domestic product declines in *absolute terms* from peak to trough, it is known as a classical cycle. Growth cycles are identified by variations in the *rate of growth* of gross domestic product. As economies developed rather rapidly in the post-war period, growth cycles predominated. The duration of business cycles in South Africa normally vary from three to five years, measured from peak to peak or from trough to trough (SARB 2006:S-153). Sometimes, however, they can last for most of a decade, as was the case in the USA during the 1990s. In the charts to follow, the shaded areas represent the upswing phases of the business cycle in the South African economy, as dated by the SA Reserve Bank. These shaded areas form the backdrop to movements in certain cyclical indicators described in greater detail below.

BUILDING COSTS AND FORECASTING IN GENERAL

Quantity surveyors find building cost forecasts useful when estimating. From the large body of research on building costs and forecasting, undertaken during the past four decades, several important studies have been selected. Though this list does not purport to be comprehensive, these studies indicate to some extent the progressive development of the field. Kilian (1972) showed that shortages of labour and materials created serious bottlenecks and contributed to rising building costs. Swart (1974) studied price formation in the South African housing industry. Bowen (1980) investigated the feasibility of producing an econometric cost model for framed structures by means of regression analysis.

Tysoe (1981) analysed various construction cost and price indices in use in the UK and how these could be applied to enhance cash flow projections. Flanagan and Norman (1983) investigated the accuracy and monitoring of quantity surveyors' price forecasting for building work. They developed a simple feedback mechanism to improve forecasting performance. Bowen and Edwards (1985) assessed the state of cost modelling and price forecasting prevailing in the South African building industry and concluded that expert systems, a form of artificial intelligence, held exciting possibilities for the future.

Taylor and Bowen (1987) examined techniques and applications related to the forecasting of building price levels. They found that of the more simplistic methods, the classical decomposition (time-series) method permits the introduction of judgement, but fails to model the changing process adequately. The Box-Jenkins modelling system yielded superior results in their study. Snyman (1989a, 1989b) described the various phases of the business cycle and, using time series data, explained in a pragmatic way how the business cycle influences building costs.

Fellows (1991) evaluated the accuracy of building cost and tender price indices and demonstrated that stochastic time series forecasting is a useful approach. Hindle (1991, 1993) focused on fluctuations in the demand for construction caused by business cycles, and on pricing policies and tendering strategies employed by building contractors. Blair *et al*. (1993) analysed the forecasting problem in terms of time series methods and noted that construction cost escalation remains a risk factor to be shared by the contractor and the owner. Bowen (1993) undertook a communication-based examination of price modelling and price forecasting in the design phase of the traditional building procurement process.

To improve forecasting of building demand levels and building costs, Snyman (1994) developed leading indicators for the South African building industry. Akintoye and Skitmore (1994) found that construction price appeared to be an important elastic influence in housing construction, but not so in the case of commercial and industrial construction. Ming *et al*. (1996) investigated how an Australian building firm's profits changed as market conditions changed. Akintoye *et al*. (1998) examined macroeconomic leading indicators of UK construction contract prices. They found that the unemployment level, construction output, industrial production and the ratio of price to cost indices in manufacturing are consistent leading indicators of construction prices. The approach put forward in the current paper is based on the understanding that fluctuations in the business cycle cause movements in builders' input costs and in tender prices. It is based on a judgemental forecasting approach in which knowledge of the cyclical features of key building cost indicators is paramount.

BUILDING COST INDICATORS IN USE IN SOUTH AFRICA

There are two building cost indicators commonly used in South Africa. The first of these is a composite index of building contractors' input costs: labour, materials, plant and fuel. It is a weighted index of the prices of units of inputs and does not make any allowance for changes in builders' profit margins or productivity. It is colloquially known as the "Haylett Formula" and forms the basis of the Contract Price Adjustment Provisions used in the South African building industry (readers from the UK will recognize its similarity to a "Baxter Formula"). This system of indexation relies on a number of Work Groups that relate to various trades in the building industry. These indices are published by Statistics South Africa, Pretoria.

The second index commonly used is the BER Building Cost Index, compiled by the Bureau for Economic Research at Stellenbosch University. This quarterly index is based on an analysis of accepted tenders. Twenty-two representative items, common to all buildings, are extracted from accepted bills of quantities. Current rates are then compared to base rates to yield a useful index of trends in tender prices. This tender price index therefore measures the market prices of building projects because it includes the profit margins of building contractors. Indeed, this special feature distinguishes it from the Haylett indices described above. As an aside, it should be mentioned that the BER Building Cost Index is somewhat of a misnomer in that it measures builders' output prices, rather than their input costs. One can see that a particular builder's output price is a client's input cost, thus making the name more appropriate. The BER refers to it as a building cost index for historical reasons, for marketing purposes, and for representing the cost to clients. Figure 1 depicts these two key building cost indicators during the period 1975 to 2006.

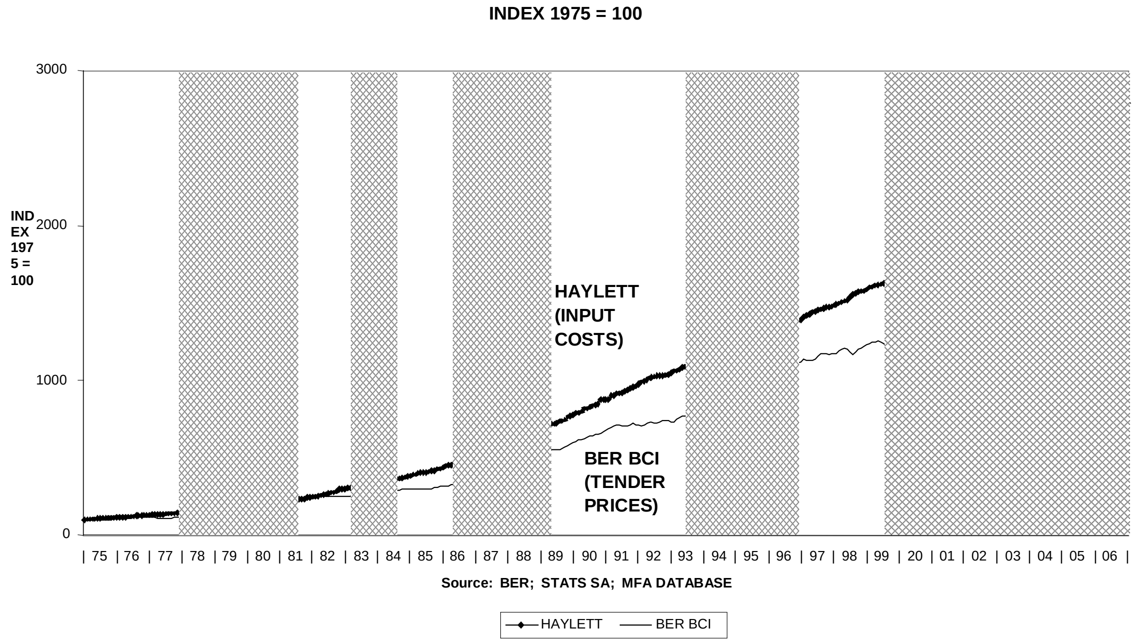


Figure 1: Haylett and BER building cost index comparison

FORECASTING BUILDING COSTS

In subsequent paragraphs, various cost factors will be considered. To forecast the future course of labour costs, one requires knowledge of labour rates, the bargaining power of labour unions, general inflationary trends, as well as the availability of skilled and unskilled labour. Similarly, to forecast the expected course of building materials prices, one needs to acquire knowledge of the degree of competition amongst building materials manufactures and merchants, their pricing policies and the way that increases in energy and transport costs affect them. Thus, the forecaster needs a profound knowledge of labour and product markets. Figure 2 depicts the cyclical indicators representing the availability of labour and materials, as derived from qualitative business surveys compiled by the Bureau for Economic Research at Stellenbosch University. Respondents are asked whether they experience shortages in the supply of labour and materials. Observe that the percentage of respondents reporting bottlenecks increases during growth phases in the economy and that supply conditions improve during recessions.

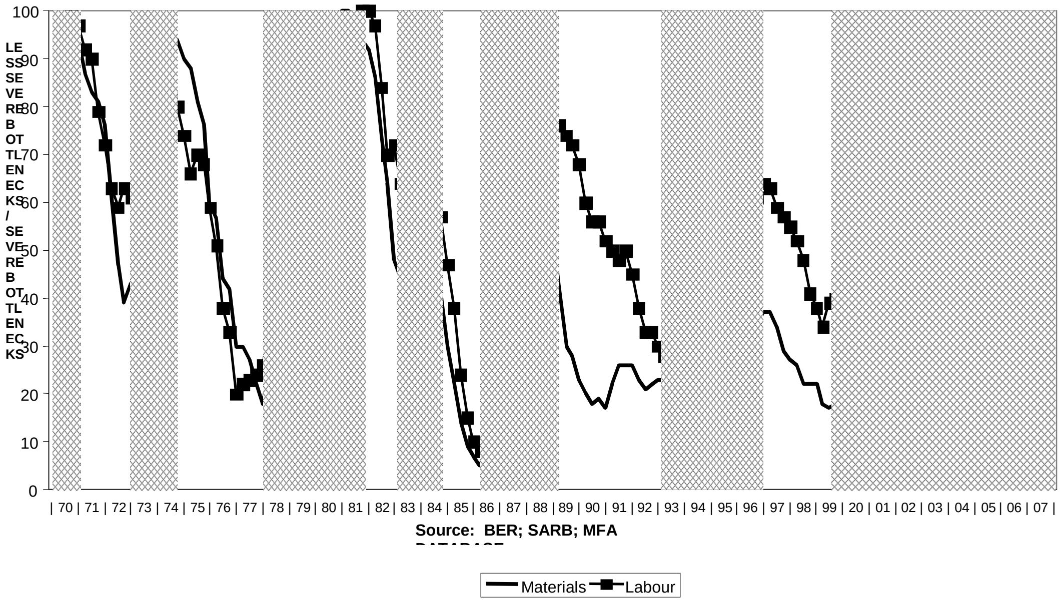


Figure 2: Labour and materials shortages

South Africa is a developing economy and many plant items are imported. In determining the future course of local plant and equipment prices, the single most important factor to consider is the exchange rate of the rand, South Africa's currency unit. The rand exchange rate has been volatile during recent years. This is the case because of fluctuations in trade and capital flows, leading to a heavily traded currency that is also subject to speculative pressures. Even though buildings are not exported, the South African building industry cannot escape the destabilizing effects of fluctuations in the rand exchange rate. Given a weaker rand, the suppliers of construction plant and equipment items have little choice but to raise local selling prices. When the rand strengthens against a basket of currencies, they are in a position to curtail local price adjustments (Kilian and Snyman 1981; Snyman 2006). This well-established pattern is shown in Figure 3 that depicts the annual percentage change in the index of construction plant, as compiled by Statistics SA. Also shown is the annual percentage change in the real effective rand exchange rate. This is a trade-weighted index, adjusted for inflation, as compiled by the SA Reserve Bank. The movements in plant prices are read off the left-hand scale. Please note that for the sake of easy comparison, the rand exchange rate fluctuations have been *inverted* and are to be read off the right-hand scale.

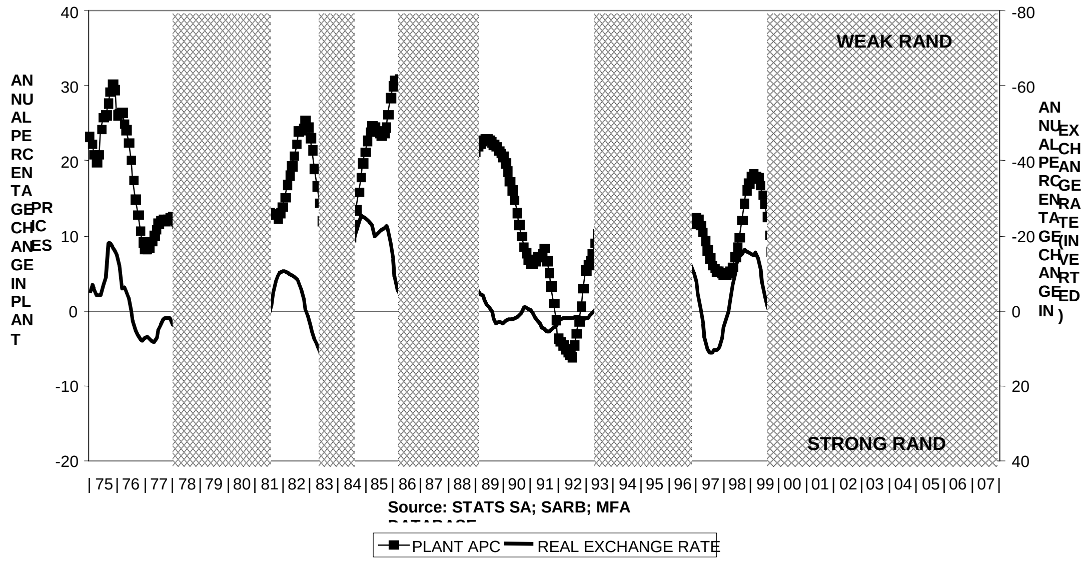


Figure 3: Movements in plant prices and the real effective rand exchange rate

Observe that the rand was weak in 1975, 1981/82, 1984/85, 1988/89, 1996, 1998/99 and 2000/01. Generally speaking, these were years of economic recession. During these periods, plant prices rose rapidly – in certain cases (1975, 1985 and 2001/02), by as much as 30% per annum. It is also evident in the chart that in two instances the annual rate of change of plant prices became negative. Thus, in 1992 plant prices were lower than in 1991. In similar vein, plant prices in 2003/04 were lower in absolute terms than in 2002. Both these events occurred in conjunction with a stronger currency after a period of rand weakness. Thus, it can be expected that price formation in the market for construction plant and equipment will remain subject to the vagaries of the rand exchange rate in coming years. This knowledge assists one in forecasting trends in construction plant prices.

Next, the focus shifts to the BER Building Cost Index. This index has been the subject of periodic scrutiny to ascertain its validity (Brook 1974; Kilian 1980; Snyman 1980; Brook 1985; Segalla 1991, Marx 2005). This tender price index has a database starting in 1962 with a rather interesting cyclical history presented in Figure 4 in the form of annual percentage changes.

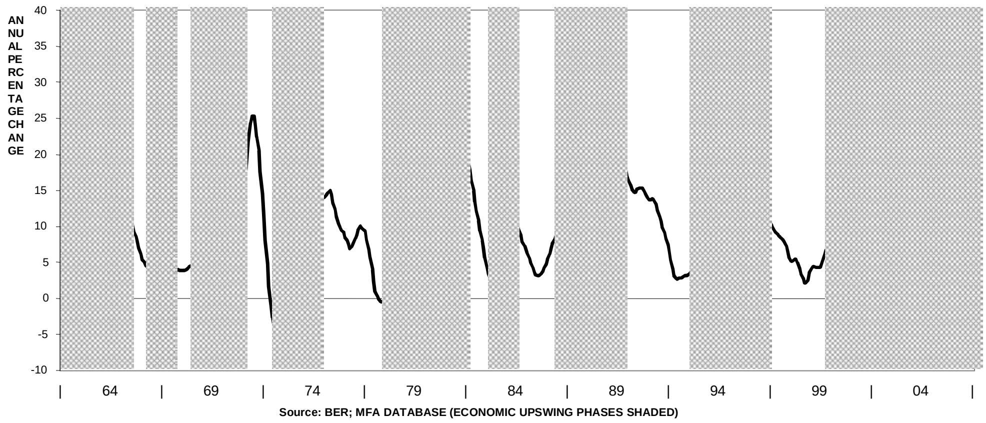


Figure 4: BER building cost index annual percentage change 1962–2006

The cyclical features evident in Figure 4 can be summarized briefly as follows.

- During the upswing phase of the business cycle (i.e. the shaded area), the index of tender prices rises more rapidly.
- During the downswing phase of the business cycle, the index rises less rapidly.
- During two severe recessions (1971/72; 1976/77), the index actually becomes negative on a year-on-year basis.
- The index usually rises more rapidly in the long upswing phases than during the shorter growth phases.
- The annual percentage change usually peaks towards the end of a growth phase in the business cycle.
- In recent times, from about 2000 onwards, the index has reflected a rather unstable rate of change. This can be ascribed, in part, to instability of the rand exchange rate, as explained above. This upswing phase is the longest on record and differs from previous ones in that it is characterized by an inflation-targeting monetary policy and responsible fiscal policy (small budget deficits).

Having considered the cyclical behaviour of tender prices, the following list summarizes the causal factors. During an upswing phase in the business cycle, building demand is usually buoyant, with several consequences (Hillebrandt 1974; Bon 1989; Snyman 1989b), given below.

- Labour rates, building materials and plant prices tend to accelerate.
- Discounts on building materials prices, offered by building suppliers to contractors, are reduced.
- Due to the perennial shortage of skilled labour, the flow of work is interrupted, bottlenecks are experienced on site, labour piracy is commonplace and management is over-extended. Consequently, labour productivity declines, with a concomitant rise in actual labour costs (as distinct from wages).
- As building contractors are forced to meet completion dates, they are obliged to employ more people. However, in the short term the supply of labour is at a premium because training programmes are abandoned in recessionary periods. Many unskilled workers are now pressed into skilled jobs. The inevitable result is that the average level of skills and the quality of building work both tend to decline.
- Given the oligopolistic nature of the market for building materials in South Africa, as well as the long lead times for new investment to create additional production capacity, acute shortages of building materials develop in the short term.
- Given the abundance of new building work, contractors avail themselves of the opportunity to widen their profit margins to recoup losses and/or to maximize current profits.
- The operational and financial risks facing building contractors (Hillebrandt 1974: 162–6) tend to increase because of prevailing bottlenecks and the need

for additional capital for expansion. Actual profits are rarely equal to planned profits because of extended project durations and cost overruns.

- Probably the single most important factor influencing the course of tender prices is the degree of competition in tendering, described in greater detail below.

All of these cyclical factors combine to propel tender prices sharply upward during a growth phase of the business cycle. Naturally, during a building recession, these factors work in the opposite direction to contain excessive tender price increases. Competition in tendering, operating as a powerful economic force, requires special attention in this regard. Figure 5 depicts the degree of competition in tendering, as derived from business surveys conducted by the Bureau for Economic Research at Stellenbosch University. Building contractors are asked to say whether they experience competition in tendering as "keener", "the same" or "less keen". The indicator in Figure 5 represents the perceptions of respondents who experienced keener competition. Observe that the degree of competition in tendering eases during an upswing phase of the business cycle. In contrast, when building work becomes scarce during severe recessions in the building industry, competition intensifies.

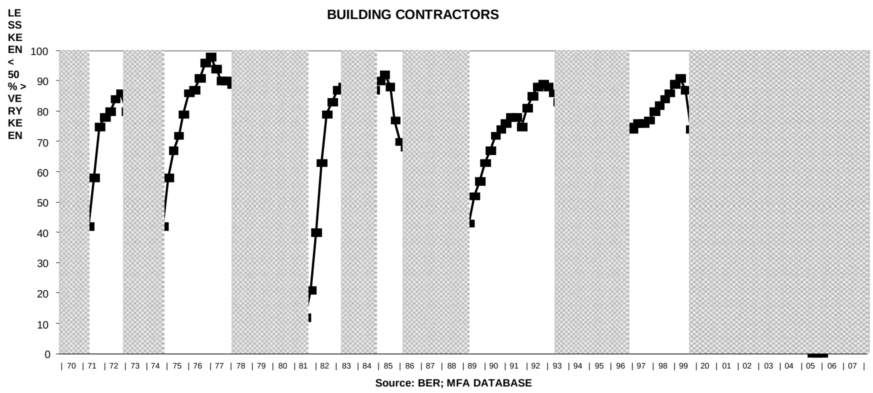


Figure 5: The degree of competition in tendering

When this indicator is inverted, and is compared to movements in tender prices on the same time scale, an inverse relationship becomes evident. Figure 6 depicts the annual percentage change in tender prices (similar to Figure 4) with the cyclical indicator of the degree of competition in tendering superimposed on it. The movements in tender prices are read off the left-hand scale with competition being read off the inverted right-hand scale. This is done to highlight the coincidence of turning points in these two cyclical indicators. Despite their diverse nature, the picture that emerges is one of fairly regular cyclical behaviour. When competition in tendering eases, tender prices rise more rapidly; when competition intensifies, tender prices rise less rapidly. This knowledge assists one in forecasting the course of tender prices.

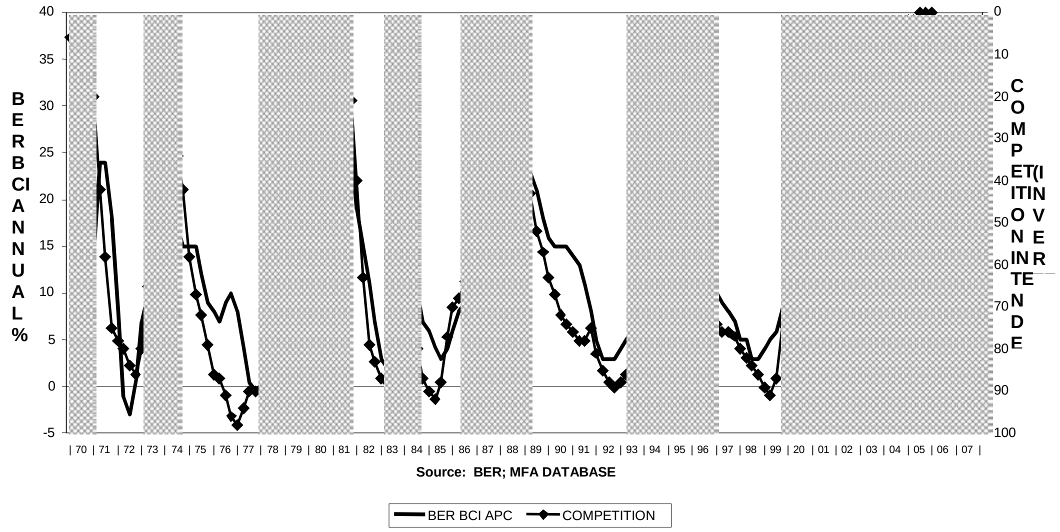


Figure 6: Comparison BER BCI annual percentage change and competition in tendering

It has been emphasized that fluctuations in tender prices are strongly influenced by fluctuations in the degree of competition in tendering. Competition in tendering affects profit margins in a direct manner: the less work available to tender on, the keener the competition for any particular project. Conversely, the more work available, the less keen the competition. It has been shown that the business cycle influences the degree of competition in tendering. It follows logically that the business cycle also influences the profitability of building contractors.

To gauge the effect of the business cycle on profitability and productivity trends, a cyclical indicator is compiled by comparing movements in tender prices with input costs. The BER Building Cost Index is an analysis of accepted tenders and includes profits of building contractors. The Haylett Index is a composite index of builders' input costs. It does not include profits. By dividing the tender price index (inclusive of profits) by the Haylett Index (exclusive of profits), one can derive the trend in the profitability and productivity of builders.

A number of features are noteworthy. First, observe that the derived indicator has dropped over the long term (1970–2000). This can be ascribed to long-run productivity improvements. Second, it is evident that profitability generally improves during a growth phase in the business cycle. It deteriorates during a recessionary period. These short-run fluctuations are due to changes in profit margins of builders who are faced with keener competition in recessionary phases of the business cycle. A similar trend is evident in census data relating to profitability in the South African construction industry and a comparison with the market conditions index derived above presents an opportunity for future research.

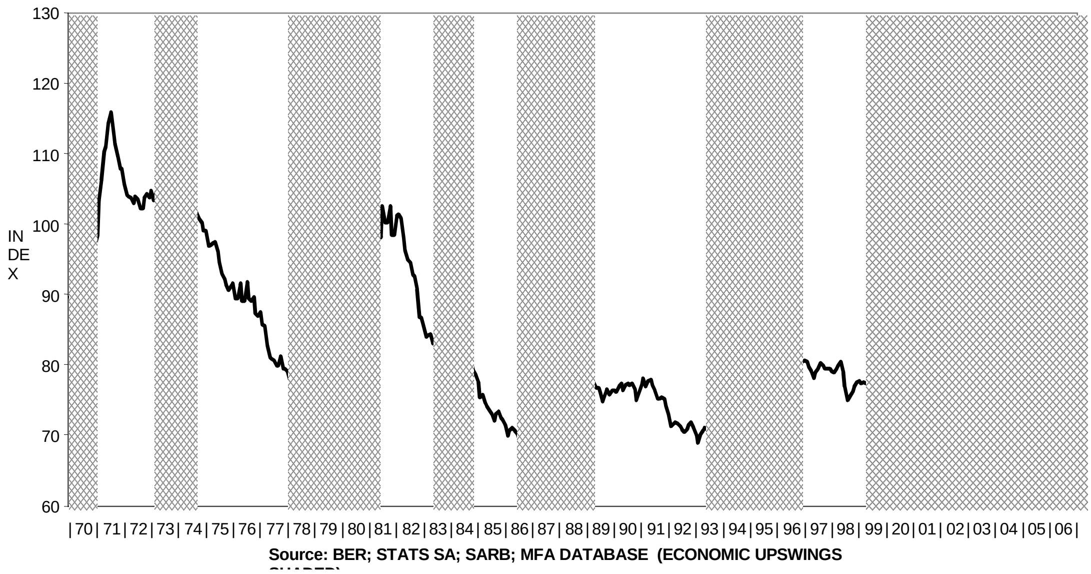


Figure 7: Profitability indicator (output prices divided by input costs)

CONCLUSIONS

When making informed forecasts of building costs, it is important to consider the course of the business cycle. This is necessary because the upswing and downswing phases of the business cycle affect the course of building costs in different ways. In growth periods in the economy, there is usually plenty of work for builders to tender on. The degree of competition in tendering eases and this allows building contractors to widen their profit margins. Yet, actual profits do not necessarily equal planned profits because building contractors normally experience cost-raising bottlenecks in the supplies of labour and materials. During recessions, the opposite would apply: bottlenecks would ease, productivity would improve, competition would intensify and tender prices would rise less rapidly. It has been shown that business cycle surveys can be useful when forecasting builders' input costs and tender prices. Thus, knowledge of trends in cyclical indicators representing the availability of labour and materials, competition in tendering and the profitability of building contractors can assist building economists in improving their ability to forecast building costs in South Africa.

REFERENCES

Akintoye, A and Skitmore, M (1994) Models of UK private sector quarterly construction demand. *Construction Management and Economics*, **12**, 3–13.

Akintoye, A, Bowen, P A and Hardcastle, C (1998) Macro-economic leading indicators of construction contract prices. *Construction Management and Economics*, **16**, 159–75.

Blair, A N, Lye, L M and Campbell, W J (1993) Forecasting construction cost escalation. *Canadian Journal of Civil Engineering*, **20**(4), 602–12.

Bon, R (1989) *Building as an economic process. An introduction to building economics*. Englewood Cliffs, NJ: Prentice Hall.

Bowen, P A (1980) *An investigation into the feasibility of producing an econometric cost model for framed structures*, Unpublished MSc (Construction Management) Thesis, Department of Building, Faculty of Engineering, Heriot-Watt University, Edinburgh. September.

Bowen , P A and Edwards, P J (1985) Cost modelling and price forecasting: practice and theory in perspective. *Construction Management and Economics*, **3**, 199–215.

Bowen, P A (1993) *A communication-based examination of price modelling and price forecasting in the design phase of the traditional building procurement process in South Africa*, Unpublished PhD Thesis, Department of Quantity Surveying, University of Port Elizabeth.

Brook, D E (1974) Building cost index: How it works and how to use it. *BER Building Survey No 21*. Bureau for Economic Research, University of Stellenbosch, December.

Brook, D E (1985) The BER Building Cost Index: recent refinements. *BER Building Survey No 65*, University of Stellenbosch, March.

Fellows, R F (1991) Escalation management: Forecasting the effects of inflation on building projects. *Construction Economics and Management*, **9**, 187–204.

Flanagan, R and Norman, G (1983) The accuracy and monitoring of quantity surveyors' price forecasting for building work. *Construction Management and Economics*, **1**, 157–80.

Hillebrandt, P M (1974) *Economic theory and the construction industry*. London: Macmillan.

Hindle, R D (1991) *The business cycle, demand for construction and appropriate selling methods for contractors*, Unpublished MSc (Construction Management) Thesis, Department of Construction Economics and Management, University of Cape Town.

Hindle, R D (1993) The effects of the short term business cycle on the construction industry. *In:* E D Manso and H Plat (Eds.) *Proceedings of CIB W55 Symposium on Economic Evaluation and the Built Environment, Vol. 2*, Laboratorio Nacional de Engenharia Civil, Lisbon, September.

Kilian, W F (1972) Inflation in the building industry. *BER Building Survey No 15*. Bureau for Economic Research, University of Stellenbosch, September.

Kilian, W F (1980) An assessment of the BER Building Cost Index. *BER Building Survey No 47*, Bureau for Economic Research, University of Stellenbosch, September.

Kilian, W F and Snyman, G J J (1981) A comparison of the BER Plant Index with the Rand-Parity Index. *BER Building Survey No 33*, Bureau for Economic Research, University of Stellenbosch, March.

Marx, H (2005) *Correctness of the BER Building Cost Index.* Confidential research report commissioned by the Bureau for Economic Research, University of Stellenbosch. Undertaken by the Department of Quantity Surveying and Construction Management, University of the Free State, June.

Ming, C S, Runeson, G and Skitmore, M (1996) Changes in profit as market conditions change: An historical study of a building firm. *Construction Management and Economics*, **14**, 253–64.

Segalla, U (1991) The BER Building Cost Index – an overview. *Studies in Economics and Econometrics*, **15**(1), 43-57. Bureau for Economic Research, University of Stellenbosch.

Snyman, G J J (1980) On building cost indicators. *BER Building Survey No 44*. Bureau for Economic Research, University of Stellenbosch, January.

Snyman, G J J (1989a) When is a recession not a recession? A somewhat lighthearted look at the business cycle and forecasting. *Juta's South African Journal of Property,* **5**(1), 11–17.

Snyman, G J J (1989b) How the business cycle influences building costs. *Juta's South African Journal of Property,* **5**(3), 38–44.

Snyman, G J J (1994) *The development of leading indicators for the South African building industry using qualitative and quantitative data*, unpublished PhD Thesis, Department of Construction Economics and Management, University of Cape Town.

Snyman, G J J (2006) *Report on building costs: Fourth quarter 2006*. Medium-Term Forecasting Associates, Stellenbosch, December.

South African Reserve Bank (2006) *Quarterly Bulletin December 2006 No 242.* Pretoria.

Swart, C B (1974) *Faktore wat die boukoste van woonhuise beïnvloed. (Factors that influence homebuilding costs)*, unpublished MCom Thesis, Department of Business Economics, University of South Africa, Pretoria.

Taylor, R G and Bowen, P A (1987) Building price level forecasting: an examination of techniques and applications. *Construction Management and Economics*, **5**, 21–44.

Tysoe, B A (1981) *Construction cost and price indices. Description and use*. London: Spon.

THE PRACTICE OF CONSTRUCTION MANAGEMENT

J.J. Smallwood[1]

Department of Construction Management, Nelson Mandela Metropolitan University, PO Box 77000, Port Elizabeth, 6013, South Africa

International literature indicates that supervision, communication, motivation and leadership are the top ranked skills required for practising construction management – the discipline of managing a construction business and/or project(s). Whereas operational and middle management require more skills and knowledge in operational programming, labour forecasting and organization, top management requires more skills and knowledge in competitive tendering, costing and estimating, and analysis of project risk. The research reported on in the paper constitutes phase 2 of the study 'The practice of construction management'. The findings include that administration, oral communication, controlling, coordinating, decision making and leadership are skills ranked among the top 10 for all levels of management. Other findings include that contract administration, contract documentation, cost control, building methods and quality management are subject areas ranked in the top 10 positions for all levels of management. The paper concludes that the most frequently used subject areas reflect the focus at the respective levels of management: top – the management of the business of construction; middle – the management of a number of projects, and operational – the management of specific projects.

Keywords: construction management, discipline, knowledge, skills.

INTRODUCTION

Drucker (1955) states the three jobs of management as: managing a business; managing managers; and managing worker and work. He contends that although the three jobs can be analysed separately, studied separately, appraised separately, and despite each having a present and a future dimension, management cannot separate them nor can it separate decisions on the present from decisions on the future. Clearly, management is concerned with the business environment and work per se, and furthermore, it is concerned with planning – decisions regarding the future.

According to Fellows *et al.* (1983), construction management can be viewed in two dimensions, the management of the business of construction and the management of projects per se. They emphasize that in practice, the two dimensions are interdependent. Lavender (1996) emphasizes that the differences between managing the business of construction and projects should not be overstated, but that they should be noted. Whereas the former is ongoing, projects are unique, of a temporary nature, entail a series of deadlines and targets and the establishment of a project team.

Frederick W. Taylor, while working in the steel industry during the early 1900s identified the need for a systematic and scientific approach to industrial management. He proposed that managers realize order and system to their work in the form of 'scientific management', and suggested that managers should condense the great mass

[1] john.smallwood@nmmu.ac.za

of traditional knowledge to a science by classifying, tabulating and reducing it to rules, laws and formulae. He recommended that managers plan the work of the people reporting to them and devise means of coordination and control. His plan called for managers to motivate their people by selecting, teaching and developing the workers and 'heartily cooperating with them'. Effectively, he identified the need to systematize management, analyse the work to be done, measure it, and assign portions thereof to the people best able to execute it (Allen 1958). Allen (1958) contends that although Taylor did not provide the whole answer to 'What is a manager?' he enabled us to take a long stride forward.

Henri Fayol's book *General and industrial management* published in 1916 in French is regarded as the first attempt to derive general principles of management (Lavender 1996). He identified six key activities that take place in an industrial organization: technical such as production; commercial such as purchasing and selling; financial such as obtaining long-term and working capital; security in the form of taking care of the organization's property; accounting such as compiling and maintaining financial information; and managerial. Fayol then identified five processes relative to the managerial activities: forecasting and planning; organizing; commanding; coordinating; controlling (Lavender 1996).

Allen (1973) subdivides the order of management work into functions – planning, organizing, leading and controlling, and suggests a fifth in the form of coordination. Allen (1985) elaborates on management as an art, science and profession in his book *The management profession*.

Based upon his interpretation of the term 'management', Allen (1983) evolves a succinct definition for a professional manager: 'A management leader who specializes in the work of planning, organizing, leading and controlling through the systematic use of classified knowledge, concepts, principles and a common vocabulary, and who subscribes to the standards of practice and a code of ethics established by a recognized body.'

The nine recognized functions in an organization provide further insights relative to the knowledge and skills required by construction managers: general management; production; procurement; marketing; financial; human resources; public relations; legal; and administration and information technology. Generally, the organization structures of contracting and related organizations, dependent upon size, are structured according to these functions. Successful management of the business of construction, which includes managing projects, is dependent upon effective integration of these functions. Furthermore, although the production function mostly takes place on projects, it is merely one of the functions and is dependent on the others, and vice versa.

Given that the environment within which construction management is practised changes, the debate surrounding the content of construction management undergraduate courses, and a pending scoping exercise by the Building Construction Standards Generating Body, the study 'The practice of construction management Phase 2' was initiated to investigate the frequency of use of knowledge areas and skills.

Research of this nature is important as the findings inform tertiary institutions presenting construction management programmes, and related councils and institutes, which are the custodians of knowledge, and responsible for the development of initial skills, registration of practitioners, maintenance of standards and continuing professional development (CPD).

REVIEW OF THE LITERATURE

Functions and activities of management work

Allen (1973) identifies two classes of work – mechanical and human. He then subdivides the class of human work into the orders of management work and technical work. Technical work entails physical and mental effort by the person doing the work. Management work also entails physical and mental effort, but by a person in a leadership position to realize results through other people. He then subdivides the order of management work into functions – planning, organizing, leading and controlling, and suggests a fifth in the form of coordination. The functions of management work are then subdivided into activities:

- Planning: forecasting, developing objectives, programming, scheduling, budgeting, developing procedures and developing policies;
- Organizing: developing organization structure, delegating and developing relationships;
- Leading: decision making, communicating, motivating, selecting people and developing people; and
- Controlling: developing performance standards, measuring performance, evaluating performance and correcting performance.

Certain activities are subdivided into segments:

- Developing objectives: establishing key, critical and specific objectives; and
- Developing organization structure: establishing functional and divisionalized organization structure.

Knowledge and skills

According to Fryer (1990) in 1971 Robert Katz identified three broad classes of skills: human, technical and conceptual. Human skill is the manager's ability to work as a group member and build cooperative effort in the team, communicate and persuade. Technical skill includes proficiency in some aspect of the organization's work, analytical abilities, and specialized knowledge and techniques. Conceptual skill is the ability to adopt a holistic perspective relative to the organization. Katz argued that human skill is important at all levels of management, but especially at operational level, as such managers have wide-ranging and frequent contact with people. Operational management also relies heavily on technical skill, but this is less important for top management, which depends more on conceptual skill. Katz further argued that many management tasks require the use of several skills – for example, resolving a technical problem may require more than technical skill as it may affect people.

Fryer (1990) focuses on interpersonal, informational and decisional skills due to Mintzberg's contention that managers perform an intricate set of overlapping roles, namely interpersonal, informational and decisional. In terms of interpersonal skills, construction managers ranked human skills highest during a study conducted by Fryer (1990) in 1977 to investigate the development of managers in the construction industry. Relative to social skills, site managers and contracts managers stressed the need for keeping people informed, getting them involved in tasks, fostering cooperation and teamwork, communicating clearly, dealing with people as individuals, and showing an interest in people.

Phase 1 of the study 'The practice of construction management' entailed a national postal survey of non-student members of the South African Institute of Building (SAIB) (Smallwood 2000). The objectives of the study were to determine, based on frequency of use, the importance of skills and areas of knowledge per level of construction management. Respondents were asked to identify the frequency at which skills and knowledge pertaining to subject areas are required, using the range of responses: frequently, sometimes, rarely or never.

It is significant that all five functions of management work are represented in the top 10 ranked skills of operational, middle and 'all' levels of management: controlling, coordinating, planning, leadership and organizing. Planning and organizing are not included in the top 10 ranked skills of top management (Table 1). It is notable that the importance indexes (IIs) for the top eight ranked skills for all levels of management are above the midpoint value of 1.50 indicating prevalence in terms of use. Effectively, costing is more important to top and middle management, whereas interpersonal, organizing, planning and plan-reading skills are more important to operational and middle management.

Table 1: Importance of skills per level of construction management based on frequency of use (Smallwood 2000)

Skill	Level of management							
	Operational		Middle		Top		All	
	II	Rank	II	Rank	II	Rank	II	Rank
Communicating (oral)	1.29	2	1.69	3	1.80	1=	1.59	1
Controlling	1.27	3=	1.71	1=	1.76	3	1.58	2=
Decision making	1.22	8=	1.71	1=	1.80	1=	1.58	2=
Coordinating	1.24	6=	1.63	6=	1.75	4=	1.54	4
Administrative	1.22	8=	1.63	6=	1.75	4=	1.53	5=
Planning	1.27	3=	1.68	4	1.63	13	1.53	5=
Leadership	1.20	10=	1.59	10=	1.73	7	1.51	7=
Organizing	1.25	5	1.64	5	1.64	12	1.51	7=
Communicating (written)	1.15	14	1.58	13	1.75	4=	1.49	9
Interpersonal	1.20	10=	1.59	10=	1.61	14=	1.47	10

Respondents were also required to respond regarding the importance of subject areas based on the frequency of use of related knowledge (Table 2). Given that cost, quality and time are the traditional project performance measures and parameters, it is significant that cost control, quality management and planning (programming) are ranked in the top 10 subject areas for the operational, middle and top levels of management, with the exception of planning (programming) for top management. It is notable that relative to the 'all' levels of management there are only two subject areas for which the IIs are above the midpoint value of 1.50, namely construction methods (building) and cost control.

Contract administration, contract documentation, cost control, construction methods (building) and quality management are in the top 10 ranked subject areas for operational, middle and top levels of management. Customer service is only common to middle and top management; measuring quantities, programming and subcontractor management are common to operational and middle management.

Table 2: Importance of subject area per level of construction management based on frequency of use of knowledge (Smallwood 2000)

Subject area	Level of management							
	Operational		Middle		Top		All	
	II	Rank	II	Rank	II	Rank	II	Rank
Construction methods (building)	1.22	1	1.80	1	1.59	6=	1.54	1
Cost control	1.15	3	1.75	2	1.64	2=	1.51	2
Quality management	1.14	4	1.63	6	1.59	6=	1.45	3
Contract administration	1.08	5=	1.66	3=	1.58	9	1.44	4=
Subcontractor management	1.19	2	1.58	8=	1.54	12=	1.44	4=
Contract documentation	0.98	10=	1.66	3=	1.59	6=	1.41	6
Planning (programming)	1.07	7	1.61	7	1.47	17	1.38	7
Customer service	0.85	19	1.56	10	1.71	1	1.37	8
Project management	0.86	18	1.66	3=	1.54	12=	1.35	9
Productivity	0.90	14	1.53	12	1.46	18=	1.30	10

RESEARCH

Sample stratum and methodology

A survey 'The practice of construction management Phase 2' was conducted among non-student members of the Chartered Institute of Building (CIOB) (Southern Africa) to determine the frequency at which 78 knowledge areas and 45 skills are used relative to the three levels of management. The primary objective of the survey was to provide 'current' data for reference by the Building Construction Standards Generating Body (SGB) during a management scoping exercise.

A questionnaire was mailed to members, and also circulated electronically to those members with e-mail addresses. Ninety-one responses were included in the analysis of the data from a net sample frame of 648, which represents a response rate of 14% (91 / (656 – 8)].

Analysis and presentation of the data

Given that respondents were required to respond in terms of a frequency range: never, monthly, fortnightly, weekly and daily, it was necessary to compute an importance index (II) to enable a collective comparison of responses to and a ranking of the respective subject areas and skills. The II is calculated as follows:

$$II = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4}{n_o + n_1 + n_2 + n_3 + n_4}$$

where n_0 = unsure/never, n_1 = monthly, n_2 = fortnightly, n_3 = weekly and n_4 = daily.

The skills and subject areas are presented in and ranked in terms of descending frequency of use. The five ranges of II values indicate that the skills and subject areas can be deemed to be used as follows:

- $3.2 \leq 4.0$: weekly to daily/daily;
- $2.4 \leq 3.2$: fortnightly to weekly/weekly;
- $1.6 \leq 2.4$: monthly to fortnightly/fortnightly;
- $0.8 \leq 1.6$: never to monthly/monthly; and
- $0.0 \leq 0.8$: never to monthly.

Findings

Respondents were involved with the following types of construction: commercial (73.6%), industrial (51.6%), domestic (42.9%) and infrastructure (23.1%).

The 0–2 floors (67%) height category predominated in terms of the level of structures respondents were involved with, followed by ground (49.5%), below ground (27.5%), 0–10 floors (25.3%) and 0–20 floors (12.1%).

The average number of years worked in the respective levels of management by respondents increased with the seniority of the level: operational (4.3), middle (6.7) and top (9.3). There are 65.9% of respondents currently working at top management level and 25.3% and 5.5 % at middle and operational level respectively.

Tables 3 and 4 indicate the mean frequency of use of skills and subject areas for all levels of management in terms of IIs, respectively.

Oral and written communicating predominate among skills in terms of the mean for all levels of management, followed by decision making, organizing, administrative, leadership, coordinating, planning, numerical (maths), plan reading, interpersonal, motivating and controlling (II values $> 3.2 \leq 4.0$) (Table 3). However, it should be noted that leadership and controlling are more important at top management, plan reading is substantially more important at operational and middle management, and interpersonal and motivating are more important at middle and top management.

Other frequently used skills are: supervisory, computer, technical, negotiating with subcontractors and costing (II values $> 2.4 \leq 3.2$). However, it should be noted that computer skills are substantially more important at middle and top management, and negotiating with subcontractors is substantially more important at operational and middle management.

Other important differences include: measuring quantities is more important at operational management; team building, estimating and procedures development are more important at middle and top management; financial, marketing and entrepreneurial are more important at top management.

There is only one skill that is never used by the majority of all levels, namely negotiating with unions at operational management.

Mathematics predominates among subject areas in terms of the mean for all levels of management, followed by building methods (construction), materials, customer service, subcontractor management, cost control, quality management, contract administration, productivity, ethics and materials management (II values $> 2.4 \leq 3.2$) (Table 10). However, it should be noted that building methods (construction), materials, subcontractor management, cost control, quality management and materials management are more important at operational and middle management; customer service and ethics are more important at top management; and productivity is more important at operational management. Other notable differences include the importance of measuring (quantities) and surveying (land) at operational management, and negotiating, management (business), financial management, public relations, property economics, marketing, entrepreneurship, accountancy, cash flow forecasting, economics, company law, property development, property law and tax at top management.

Table 3: Mean frequency of use of skills for all levels of management in terms of IIs

Skill	Level of management							
	Operational		Middle		Top		Mean	
	II	Rank	II	Rank	II	Rank	II	Rank
Communicating (oral)	3.84	1	3.87	1	3.89	1=	3.86	1
Communicating (written)	3.65	2	3.65	2	3.75	4	3.68	2
Decision making	3.24	8	3.48	4=	3.83	3	3.51	3
Organizing	3.33	6	3.48	4=	3.63	6=	3.48	4
Administrative	3.28	7	3.44	8	3.66	5	3.46	5=
Leadership	3.16	11	3.33	10	3.89	1=	3.46	5=
Coordinating	3.44	4	3.32	11	3.59	8	3.45	7
Planning	3.21	9	3.48	4=	3.49	11	3.39	8
Numerical (maths)	3.40	5	3.47	7	3.28	13	3.38	9
Plan reading	3.58	3	3.51	3	2.85	19	3.31	10
Interpersonal	3.02	13	3.38	9	3.52	9	3.30	11
Motivating	2.98	14	3.22	12	3.63	6=	3.27	12
Controlling	3.20	10	3.00	15	3.51	10	3.23	13
Supervisory	3.04	12	3.03	13	2.74	21	2.93	14
Computer	2.14	24	3.02	14	3.46	12	2.87	15
Technical	2.81	17	2.80	17	2.78	20	2.79	16
Negotiating with subcontractors	2.90	16	2.90	16	2.37	24	2.72	17
Costing	2.46	19	2.57	18	2.52	23	2.51	18
Measuring (quantities)	2.92	15	2.33	22	1.90	32	2.38	19
Team building	2.00	25	2.49	19	2.66	22	2.38	20
Initiating	1.53	29	2.30	24	3.23	15=	2.35	21
Negotiating with project managers	2.18	22	2.46	20	2.31	26	2.31	22
Measuring (productivity)	2.48	18	2.35	21	2.02	30=	2.28	23
Communicating (graphic)	2.15	23	2.29	25	2.27	28	2.23	24
Financial	1.37	31	2.18	26	3.10	17	2.21	25
Negotiating with material suppliers	2.23	21	2.32	23	2.02	30=	2.19	26
Conflict resolution	1.92	26	2.08	27	2.29	27	2.09	27
Negotiating with clients	1.04	36	2.07	28	3.08	18	2.06	28
Estimating	1.36	32	2.00	29	2.36	25	1.90	29=
Marketing	0.69	41	1.75	34	3.27	14	1.90	29=
Entrepreneurial	0.72	39	1.61	35	3.23	15=	1.85	31
Report writing	1.77	27	1.97	30	1.71	33	1.81	32
Negotiating with plant hire	2.27	20	1.86	33	1.25	38	1.79	33
Procedures development	1.22	33	1.88	32	2.12	29	1.74	34
Training	1.61	28	1.89	31	1.70	34	1.73	35
Systems development	0.71	40	1.32	36	1.68	35	1.23	36
Design (temporary works)	1.19	34	1.26	38	1.08	41	1.17	37
Design management	0.54	43	1.27	37	1.52	36	1.11	38
Work study	1.07	35	1.18	39=	0.90	43	1.05	39
Negotiating with community	0.77	37	1.18	39=	0.98	42	0.97	40
Statistical	0.76	38	1.00	42	1.13	40	0.96	41
Research	0.64	42	0.92	44	1.18	39	0.91	42
Auditing	0.49	44	1.02	41	1.44	37	0.89	43
Surveying (land)	1.49	30	0.71	45	0.32	45	0.84	44
Negotiating with unions	0.48	45	0.95	43	0.71	44	0.71	45

Table 4: Mean frequency of use of subject areas for all levels of management (Part A)

Subject area	Level of management							
	Operational		Middle		Top		Mean	
	II	Rank	II	Rank	II	Rank	II	Rank
Mathematics	3.28	1=	3.07	1	3.24	1	3.19	1
Building methods (construction)	3.28	1=	2.98	2	2.58	9=	2.94	2
Materials	3.08	3	2.65	5	2.28	19	2.67	3
Customer service	1.92	21	2.53	7=	3.21	2	2.55	4
Subcontractor management	2.96	4	2.63	6	2.03	25	2.54	5
Cost control	2.52	9	2.73	4	2.36	15	2.53	6=
Quality management	2.79	8	2.53	7=	2.27	20	2.53	6=
Contract administration	2.14	16	2.77	3	2.48	12	2.46	8
Productivity	2.91	5	2.34	14=	2.08	23=	2.44	9
Ethics	1.93	20	2.44	10=	2.91	5	2.42	10=
Materials management	2.85	6	2.42	12	2.00	27	2.42	10=
Programming planning	2.49	10=	2.32	16=	2.32	17	2.37	12
Measuring (quantities)	2.81	7	2.31	18	1.80	34	2.30	13
Management systems e.g. quality	1.96	19	2.32	16=	2.49	11	2.25	14
Contract documentation	2.06	18	2.48	9	2.16	22	2.23	15
Negotiating	1.55	31	2.26	19	2.87	7	2.22	16=
Purchasing	2.18	14	2.41	13	2.08	23=	2.22	16=
Health and safety	2.49	10=	2.07	22	2.02	26	2.19	18
Information technology	1.62	24	2.34	14=	2.44	13	2.13	19
Project management	1.57	27=	2.44	10=	2.36	16	2.12	20
Estimating	1.47	33	2.25	20	2.38	14	2.03	21
Human resources	1.71	23	1.93	25	2.30	18	1.98	22
Civil methods (construction)	2.20	13	2.05	23	1.50	46=	1.91	23
Management (business)	0.91	49=	1.67	32	3.11	3	1.89	24
Specifications	2.29	12	2.08	21	1.92	31=	1.85	25
Plant and equipment management	2.17	15	1.88	26	1.43	52	1.82	26=
Procedures	1.76	22	1.98	24	1.74	36	1.82	26=
Financial management	0.89	51	1.86	27	2.70	8	1.81	28
Public relations	1.18	38	1.66	33=	2.58	9=	1.80	29
Property economics	0.27	70=	0.79	71	1.30	59	1.78	30
Total quality management (TQM)	1.60	25=	1.74	29	1.95	30	1.76	31
Marketing	0.72	55	1.60	36=	2.88	6	1.73	32
Codes of practice	1.60	25=	1.69	30	1.78	35	1.69	33=
Worker participation	2.13	17	1.62	35	1.34	56	1.69	33=
Entrepreneurship	0.57	65=	1.27	51=	3.07	4	1.63	35
Environment	1.30	35	1.60	36=	1.98	28=	1.62	36
Cost engineering	1.51	32	1.81	28	1.49	48=	1.60	37
Dispute resolution	1.57	27=	1.50	42	1.60	42	1.55	38
Professional practice	1.05	43	1.55	40	1.98	28=	1.52	39
Strategic planning	1.02	45=	1.60	36=	1.92	31=	1.51	40
Accountancy	0.70	56	1.60	36=	2.17	21	1.49	41
Training	1.38	34	1.68	31	1.32	57	1.46	42
Procurement systems	1.09	41	1.66	33=	1.50	46=	1.41	43
Remuneration	0.91	49=	1.53	41	1.72	37	1.38	44
Risk management	1.07	42	1.33	46=	1.66	39	1.35	45
Industrial relations	1.23	36	1.31	48	1.39	54	1.31	46
Environmental issues	1.04	44	1.29	50	1.56	43	1.29	47
Cash flow forecasting	0.60	63	1.35	44	1.81	33	1.25	48=

Table 4: Mean frequency of use of subject areas and for all levels of management (Part B)

Subject area	Levels of management							
	Operational		Middle		Top		Mean	
	II	Rank	II	Rank	II	Rank	II	Rank
Final accounts	0.85	52	1.39	43	1.53	45	1.25	48=
Labour law	1.11	40	1.24	54=	1.40	53	1.25	48=
Statistics	1.02	45=	1.30	49	1.31	58	1.21	51
Drawing (engineering/geometric)	1.57	27=	1.14	58	0.89	68	1.20	52
Commercial law	0.66	59	1.23	56	1.66	38	1.18	53
Benchmarking	0.73	54	1.27	51=	1.49	48=	1.16	54=
Service management	0.69	57=	1.34	45	1.46	50	1.16	54=
Structural principles/design	1.17	39	1.33	46=	0.91	67	1.13	56
Economics	0.57	65=	1.16	57	1.64	40	1.12	57=
Insurance	0.69	57=	1.24	54=	1.45	51	1.12	57=
Facilities management	0.57	65=	1.25	53	1.35	55	1.05	59
Design (temporary works)	1.19	37	1.07	62	0.75	72	1.00	60=
Design management	0.59	64	1.12	60	1.29	60=	1.00	60=
Industrial psychology	0.80	53	0.95	65	1.21	63	0.98	62
Physics	1.02	45=	1.09	61	0.72	73	0.94	63=
Value management/engineering	0.64	62	1.13	59	1.05	64	0.94	63=
Company law	0.27	70=	0.90	68	1.62	41	0.93	65
Surveying (land)	1.57	27=	0.80	69=	0.31	77	0.89	66
Work study	1.00	48	0.93	66	0.71	74	0.88	67
Property development	0.20	75	0.88	69=	1.54	44	0.87	68
Valuing	0.65	60=	1.00	63=	0.93	66	0.86	69
Re-engineering	0.65	60=	0.92	67	0.84	69	0.80	70=
Research	0.44	68	1.00	63=	0.97	65	0.80	70=
Property law	0.23	73=	0.77	72	1.29	60=	0.76	72
Tax	0.12	76	0.67	73	1.25	62	0.68	73
Life cycle costing	0.33	69	0.66	74	0.82	70	0.60	74
Sociology	0.24	72	0.58	75	0.64	76	0.48	75
International contracting	0.05	78	0.36	77	0.76	71	0.39	76
Conveyancing	0.07	77	0.44	76	0.65	75	0.38	77
Marine methods (construction)	0.23	73=	0.17	78	0.23	78	0.21	78

There are 11 subject areas that are never used by the majority at operational management, two at middle management and two at top management.

SUMMARY

Tables 5 and 6 provide a summary of the top 10 skills and subject areas for all levels of management in terms of ranks emanating from Phases 1 and 2 of the ‘Practice of construction management’ studies reported on in the review of the literature and the research sections above, respectively.

Table 5 indicates that relative to skills, 65 of the 80 ranks (81.3%) presented are within the top 10 of their respective studies – there is limited discordance between the findings of the two studies. Although the II values have not been presented due to the use of different scales, it should be noted that the differences between the highest and lowest ranked mean skill II values are:

- Phase 1: 0.15 on an II ranging from 0.00 to 3.00 (5%); and
- Phase 2: 0.63 on an II ranging from 0.00 to 4.00 (15.8%).

The ranking of communicating (oral), communicating (written), decision making, administrative, leadership and interpersonal, in particular the two communicating skills, amplifies the importance of the management function of leading. Furthermore, it is notable that the other four functions of management work are ranked within the top 10: organizing; coordinating, planning and controlling.

Table 5: Mean frequency of use of skills for all levels of management for Phases 1 and 2 in terms of ranks

Skill	Levels of management							
	Operational		Middle		Top		Mean	
	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
Communicating (oral)	2	1	3	1	1=	1=	1	1
Communicating (written)	14	2	13	2	4=	4	9	2
Decision making	8=	8	1=	4=	1=	3	2=	3
Organizing	5	6	5	4=	12	6=	7=	4
Administrative	8=	7	6=	8	4=	5	5=	5=
Leadership	10=	11	10=	10	7	1=	7=	5=
Coordinating	6=	4	6=	11	4=	8	4	7
Planning	3=	9	4	4=	13	11	5=	8
Interpersonal	10=	13	10=	9	14=	9	10	11
Controlling	3=	10	1=	15	3	10	2=	13

Table 6 indicates that relative to knowledge areas, 52 of the 80 ranks (65%) presented are within the top 10 of their respective studies – there is a degree of discordance between the findings of the two studies. The differences between the highest and lowest ranked mean knowledge area II values are:

- Phase 1: 0.32 on an II ranging from 0.00 to 3.00 (10.7%); and
- Phase 2: 0.82 on an II ranging from 0.00 to 4.00 (20.5%).

The ranking of construction methods (building) indicates the importance of technical knowledge. The rankings of cost control, quality management, planning (programming) and productivity reflect the status of the traditional three project parameters: cost, quality and time. The ranking of customer service reflects the status of client satisfaction – client satisfaction was ranked first among 11 project parameters during a study conducted among project managers (Smallwood and Venter, 2002). Furthermore, client satisfaction is essentially a function of performance relative to the traditional project parameters of cost, quality and time. The relevance of the other subject areas is as follows. Construction management includes the management of projects and therefore contract administration and contract documentation are important. Furthermore, both require communicating. The greater percentage of all projects is undertaken by subcontractors, and construction managers invariably interact with project managers.

CONCLUSIONS

Construction managers, certainly members of the CIOB (Southern Africa), spend a limited number of years at operational management level, and more at both middle and top management level.

The most frequently used subject areas reflect the focus at the respective levels of management: top – the management of the business of construction; middle – the management of a number of projects; operational – the management of specific projects.

Based upon their frequency of use and current tertiary education, the question arises as to the extent to which tertiary institutions and CPD address a number of skills and subject areas. The skills are: interpersonal, entrepreneurial, initiating, team building, conflict resolution, procedures development, systems development, design management, research, design (temporary works, and negotiating with the community. The subject areas are: customer service, entrepreneurship, ethics, management systems, procedures, total quality management, risk management, procurement systems, dispute resolution, benchmarking, service management, facilities management, design management, design (temporary works), research, worker participation and re-engineering.

Table 6: Mean frequency of use of knowledge for all levels of management for Phases 1 and 2 in terms of ranks

Knowledge area	**Levels of management**							
	Operational		**Middle**		**Top**		**Mean**	
	Phase 1	**Phase 2**	**Phase 1**	**Phase 2**	**Phase 1**	**Phase 2**	**Phase 1**	**Phase 2**
Construction methods (building)	1	1=	1	2	6=	9=	1	2
Cost control	3	9	2	4	2=	15	2	6=
Quality management	4	8	6	7=	6=	20	3	6=
Contract administration	5=	16	3=	3	9	12	4=	8
Subcontractor management	2	4	8=	6	12=	25	4=	5
Contract documentation	10=	18	3=	9	6=	22	6	15
Planning (programming)	7	10=	7	16=	17	17	7	12
Customer service	19	21	10	7=	1	2	8	4
Project management	18	27=	3=	10=	12=	16	9	20
Productivity	14	5	12	14=	18=	23=	10	9

RECOMMENDATIONS

Construction management undergraduate programmes need to focus on management and more specifically the management of resources within defined parameters such as cost, environment, health and safety, productivity, quality and time. However, to be able to manage resources within defined parameters requires technical expertise relative to the construction process. The findings clearly indicate the need to empower graduates to improve the construction process – customer service, health and safety, productivity and quality management. These findings correlate with the contention of Harriss (1996) that the Royal Commission in New South Wales would say that undergraduate construction management education has not added value and produced a healthy industry in Australia. Given the aforementioned findings, complementary issues need to be addressed: benchmarking, constructability, partnering, procurement systems, re-engineering and value management. Furthermore, given that construction managers spend a limited number of years at operational management level, and more at both middle and top management level and those construction managers in small and medium sized organizations need to fulfil a range of functions, construction management programmes need to empower graduates to manage the business of construction.

Councils should benchmark tertiary education programmes in terms of skills and subject areas and assess applicants applying for registration accordingly. Institutes should follow suit and engender the delivery of appropriate education and training by the providers thereof, to assure that applicants applying to upgrade their membership, and non-applicants applying for membership, will complement the discipline, practice and profession of construction management. Furthermore, institutes should evolve the requisite CPD where inadequacies in education and training have been identified, or where changes in the construction environment require such CPD. Practitioners should objectively assess their current ‘basket’ of skills and level of knowledge relative to subject areas. Tertiary institutions should assess whether they address the subject areas, and the development of the skills, and if so, the extent to which they do.

REFERENCES

Allen, L A (1958) *Management & organisation*. New York: McGraw-Hill.

Allen, L A (1973) *Professional management: new concepts and proven practices*. New York: McGraw-Hill.

Allen, L A (1983) *The Louis A Allen common vocabulary of management*. 6ed. Palo Alto: Louis A. Allen Associates, Inc.

Drucker, P F (1955) *The practice of management*. London: Heinemann.

Fellows, R, Langford, D, Newcombe, R and Urry, S (1983) *Construction management in practice*. London: Construction Press.

Fryer, B (1990) *The practice of construction management.* 2ed. Oxford: BSP Professional Books.

Harriss, C (1996) Building teaching under fire: how to respond? *Chartered Building Professional*, November, 20–23.

Lavender, S (1996) *Management for the construction industry*. Harlow: Addison Wesley Longman Limited.

Smallwood, J J (2000) Practicing the discipline of construction management: knowledge and skills. *In*: A B Ngowi and J Ssegawa (Eds.) *2nd International Conference of the CIB Task Group TG 29 on Construction in Developing Countries*, 15–17 November 2000, Gaborone, Botswana National Construction Industry Council/Faculty of Engineering and Technology, University of Botswana/Council for Research and Innovation in Building and Construction, 60–70.

Smallwood, J J and Venter, D (2002) The influence of project managers on construction health and safety in South Africa. *Australian Journal of Construction Economics and Building*, **2**(1), 57–69.

ADOPTION OF PCM TO IMPROVE GENERAL CONTRACTING: THE ITALIAN CASE

Aldo Norsa[1] and Ernesto Antonini[2]

[1]*Università Iuav di Venezia, School of Architecture, Venice, Italy*
[2]*University of Bologna, School of Architecture, Cesena, Italy*

Since 2001, Italy has interpreted in an original (but somehow awkward) way the third type of European tender procedure, introducing (through law 443 known as "*legge obiettivo*") the role of "*contraente generale*", improperly translated as general contractor. As the first case study suggests, the Italian way – compared with what the best European practice proposes – lacks a clear transfer of risks and allocation of tasks. After a brief analysis of the alternatives, the authors suggest how to improve the Italian practice (according to the European directives) and make it fit better with the PPP approach, which is the correct framework for the "*contraente generale*" variant. Both clients and contractors should adopt project-construction management (PCM) services to assure the effectiveness of all phases of the delivery process.

Keywords: client, contract law, international comparison, PPP, procurement, project-construction management

INTRODUCTION

During the past five years, Italy has tried to fill its "infrastructural gap" with a new type of procurement of public works exceeding the amount of 250 million euros, thus introducing the so-called "*legge obiettivo*" (law 443/2001, completed by decree 190/2002), which complements law 109/1994 (known as "*legge quadro*" or "*legge Merloni*") governing the award and execution of all public works contracts, including concessions and project finance initiatives, as well as the "code" extended supplies and services that fits in the new European directive framework. This piece of legislation – applied to an original list of 228 "strategic works" established by the past Government at the end of 2001 – was conceived as a sort of "fast track" for selected projects and was intended to accelerate and facilitate their delivery.

As far as this paper is concerned, it is interesting to remark that the *legge obiettivo* has introduced and disciplined the "*contraente generale*", an entrepreneur whose tasks are modelled according to the European directive 93/37 interpreting the "third type" of tendering procedure, i.e. a figure that is responsible for "the realization, by whatever means, of a work corresponding to the requirements specified by the contracting authority" (EC Directive 2004)

In English, the common translation suggested for *contraente generale* (and currently used in the Italian context) is "general contractor" but this apparently obvious correspondence does not help much as some observers think that "main contractor" better explains that the "realization by whatever means" implies not only the capacity

[1] norsa@iuav.it

to deliver all sorts of works but also to coordinate the activities on site of a number of specialized contractors.

As a matter of fact, the available literature offers an array of opinions but lacks a clear or univocal definition: the notion of *contraente generale* still remains controversial on the ground of international comparisons, especially in terms of risk allocation between public client and contractor, as discussed in a previous paper by the same authors. (Norsa and Antonini 2006)

The point is that the *contraente generale*, as defined in the Italian law, has the task of designing, building and partially pre-financing a work. Its contract is thus a variation of the engineering, procurement and construction (EPC) formula: it combines a “turnkey contract”, implying delivering on schedule at a fixed price with the specified quality, with a design, build, finance and transfer (DBFT) scheme in which the facility is transferred to the awarding authority upon completion and acceptance of the works.

The main difference lies with risk allocation as far as financing is concerned: although the *contraente generale* is required to finance the project in an initial phase, he does not assume any of the risks typical of a “concession” or a “PPP” based on the EU directives. In the Italian variation, he does not operate or manage the facility: his task is limited to the design and EPC phases. This will be examined in greater details in a “case study”.

PROCUREMENT SYSTEMS: HOW DOES CONTRAENTE *GENERALE* FIT?

Until now, not one of the 228 “strategic infrastructure” projects approved in 2001 (see chapter below) has been completed: it lacks any element to carry a deeper analysis on the new *contraente generale* scheme, based on its practical application.

Waiting for such feedback, the paper will try to discuss the profile of the *contraente generale* by comparing it with the most suitable categories issued from the internationally recognized building procurement system classification.

For the purpose of international comparison, it is useful to remind that, in the selection of the most suitable building procurement system, the approach devised by Perry (1985) appears most appropriate from the point of view of classification, as suggested by Mastermann (2002). The structure of this classification is sketched in Figure 1, which provides an overview of the entire range of building procurement systems currently in use.

Based on this classification, the possible options for our purpose are the following:

1. *Separated procurement systems or conventional systems*, where the main elements of the project-implementation process, i.e. design and construction, are the responsibility of separate organizations, e.g. design consultants, quantity surveyors and contractors. The client has all of the members of the project team to deal with and is responsible for the funding and the eventual operation of the facility.

2. *Integrated procurement systems*, where one organization – usually but not exclusively a contractor – takes responsibility for the design and construction of the project so that, in theory at least, it is the only one with which the client deals. “Design and build”, “develop and construct”, “package deal method” and “turnkey approach” are the main systems in this group. In the latter case

the contractor may well provide or arrange funding for the project and be responsible for the subsequent operation of the facility.

3. *Management-orientated procurement systems*, like “management contracting”, “construction management” and “design and manage” where the management of the project is performed by an organization working with the designer and other consultants to produce the design and manage the physical operations which are carried out by works- or package-contractors. When using such systems, the client will need to have a greater involvement with the project than when employing any of the other previously described methods.
4. *Discretionary systems*, where the contracting authority lays down a framework for the overall administration of the project, within which it has the discretion to use the most appropriate of all the procurement systems outlined above.

How does the approach involving the *contraente generale* fit within these options?

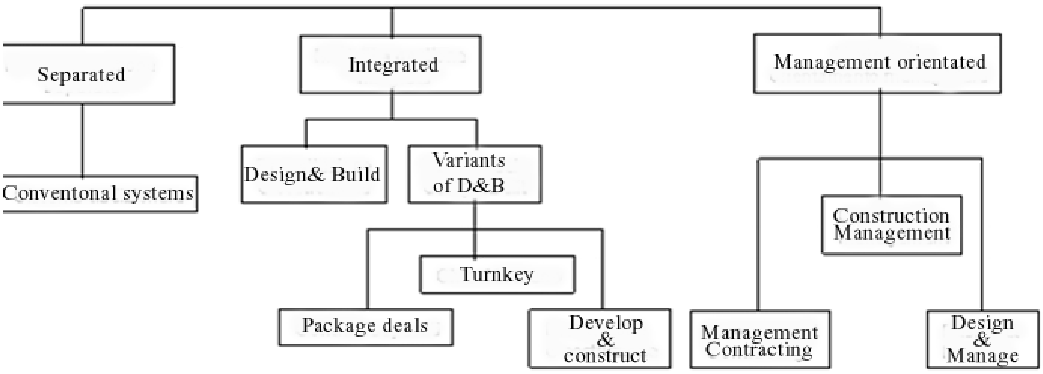


Figure 1: Systems for the management of design & construction of building projects (Mastermann 2002)

The most appropriate option to study is the second, the integrated procurement system, in order to verify how a *contraente generale* can meet the typical requirement of this process. It incorporates all the methods of managing the design and construction of a project where these two basic elements are integrated and become the responsibility of one organization, usually a contractor. Its main variant, the “design and build” procurement system, the arrangement whereby the contracting organization takes sole responsibility, normally on a “lump sum fixed price” basis, seems the model that better fits the *contraente generale* profile, although Mastermann suggests that the excellent performances in time and cost of this model depend on the typical “single point responsibility”. This advantage can only be really achieved if performance criteria are used in the formulation of the client’s requirements but unfortunately none of this kind of specifications are clearly stated by the Italian *legge obiettivo*.

As shown in Table 1, the Italian CG scheme fits (✓) only two on the three main features of a “classic” D&B scheme. Like in the generally adopted D&B model, in the GC too the contracting organization takes sole responsibility of the project and the contract is established on a lump sum fixed price. The Italian scheme does not prescribe (✕) the use of performance criteria to specify the client’s requirements.

This lack seriously jeopardizes the coherence of the framework, because it does not allow the client to make a clear evaluation of the design options proposed by the contractor.

Table 1: Comparison between D&B main features and Italian CG scheme

	D&B	Italian CG
Contracting organization takes sole responsibility	✓	✓
Lump sum fixed price	✓	✓
Client's requirements expressed by performance criteria	✓	✕

The "turnkey" is the other variant of integrated procurement systems that could be applied to the *contraente generale*. In this case, one organization, generally a contractor, is responsible for the total project from design through to when the key is inserted in the lock, turned and the facility is operational. As shown in Figure 2, the responsibility of the contractor can extend to include the installation and commissioning of the client's equipment and sometimes the identification and purchase of the site, recruitment and training of personnel, arranging of funding for the project and its operation.

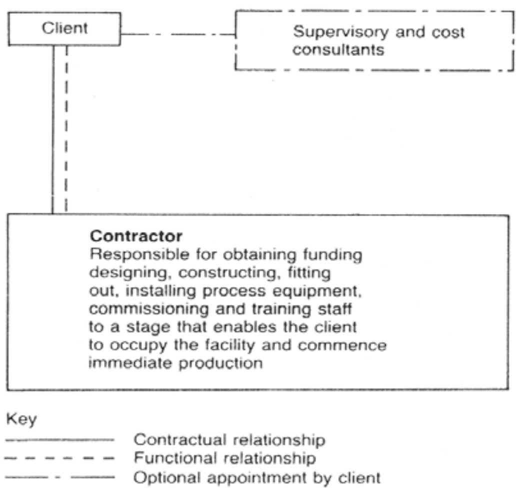


Figure 2: Functional and contractual relationship: the turnkey system (Mastermann 2002)

Because of the explicit exclusion of operating the facility, the "turnkey" system as usually adopted in international procurement does not meet the profile drawn by the Italian ad-hoc legislation. Table 2 summarizes the only partial coherence between the CG and the turnkey scheme, as internationally adopted. The CG model fits some main features of the turnkey framework (✓), but it does not fit it (✕) in order to include the operation of the project into the contractor responsibilities. It means that the contractor is only involved in the construction phase. Subsequently, the client must provide a set of specific means to check the serviceability of the project and, despite it, it remains highly exposed to the risks of unaccomplished performances.

Table 2: Comparison between turnkey main features and Italian CG scheme

	Turnkey	Italian CG
Contractor is responsible for the total project	✓	✓
Contractor's responsibility includes the installation and commissioning of client's process or other equipment	✓	✓
Contractor's responsibility includes the arranging of funding for the project	✓	✓

Contractor's responsibility includes the operation of the project	✓	✕

Another possible reference could be the third option: the management orientated procurement systems, i.e. processes whereby an organization, normally construction based, is appointed to the professional team during the initial phases of a process to provide construction management expertise under the direction of a contract administrator.

Within this framework, the "design and manage" variant seems to meet the *contraente generale* model closer than others. In this procurement system – as sketched in Figure 3 – a single organization is appointed to both design the project and manage the construction operations using package contractors to carry out the actual work. Reimbursement is by means of a lump sum or percentage management fee, with the actual cost of the works packages together with any common services being paid to the contractor when responsible for the management of the project.

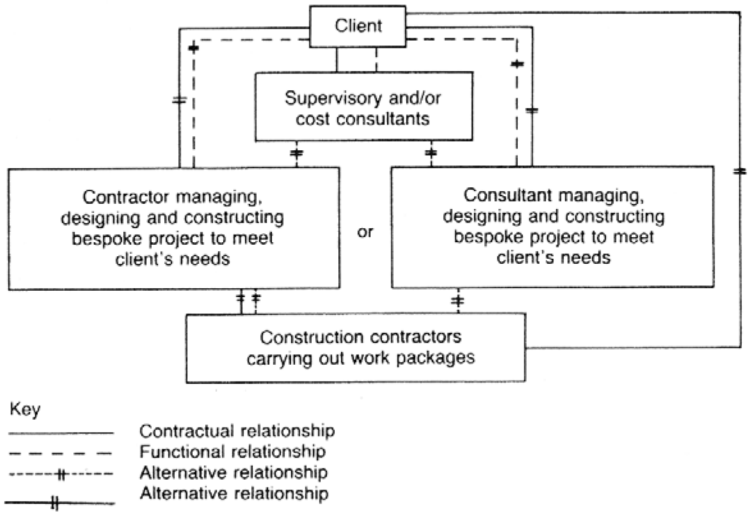


Figure 3: Functional and contractual relationship: design and manage (Mastermann 2002)

It must be noted that the appointment of an independent quantity surveyor is not envisaged by the Italian scheme, although this activity is considered compulsory by the international reference model.

Moreover, in a constructor-led design and manage approach the question of quality control is a vexed one, with the responsibility for this function nominally being allocated to the design and manage contractor but in reality usually devolving upon quality controller, independently appointed by the client.

How critical the question remains is shown by a recently published comparative analysis on 12 PPP cases in Europe, in which the key role played by means and measures of control established along the entire process is highlighted (Bougrain *et al*. 2005).

Also in this third case, depicted in Table 3, the Italian CG scheme accomplishes (✓) only with some features of the reference model: the main lack (✕) concerns the appointment of an independent quantity surveyor, which is not prescribed in the Italian scheme. It means that the client must directly provide the management of all the financial aspects of the scheme, without the support of any "third" advisor. If this solution is unadvisable in principle, it seems especially critical for the Italian public clients, which generally have very little experience in these topics.

Table 3: Comparison between D&M main features and Italian CG scheme

	D&M	Italian CG
A single organization is appointed to both design the project and manage the construction operations using package contractors to carry out the actual work	✓	✓
Lump sum fixed price	✓	✓
The client appoints an independent quantity surveyor to oversee the financial aspects of the scheme	✓	✕

"Quality control" is still an unspecified function and it is not clearly established by the *contraente generale* scheme. It remains ambiguous how the Italian legislator has intended to reinforce the client's position against the contractor, a goal that is generally achieved establishing means and measures of control during and after the construction phase. Thus resorting to professional services internationally known as project/construction management (PCM), as proposed in the Conclusions below.

The comparison between the CG scheme and the possible reference models could be summarized as follows:

- Compared to the reference models, the CG scheme establishes a "hybrid" procurement system in which the contractor assumes the sole responsibility for the total project and is appointed by the client to both design the project and manage the construction operations (like in a D&M typical scheme), and partially arrange the funding for the project (like in a turnkey system).
- The lead role of the contractor should be fortified by the application of this framework, with a subsequent expected improvement of the process efficiency, despite no evidence available at present to confirm this presumption.
- Nevertheless, the achievement of this goal seems to prevail over the need of a well-balanced risk allocation between client and contractor. In fact, the CG scheme lacks a number of measures usually adopted in the reference models to transfer some risks to the contractor, like the responsibility for the operation of the project or to improve the effectiveness of the client control on the project progress, through the appointment of independent surveying.
- Because of its hybrid profile, the CG scheme partially overlaps both the traditional general contractor and the PPP schemes currently in use in Italy. It may cause several improper analogies due to the similarity of some figures (i.e. the fund arranged by the CG to pre-finance the project and those provided in a PPP framework) and subsequent doubts and snags in the project progress.
- Except the partial pre-financing of the project (with its dubious nature), the CG scheme seems to introduce very few real innovations in the traditional "general contractor" model.

THE *LEGGE OBIETTIVO*: TIME FOR AN ASSESSMENT

Despite it, the procurement innovation introduced with the *legge obiettivo* was welcomed at first in Italy with positive comments focused on its expected effect to push forward an extensive and much-needed infrastructure programme.

However, based on the experience so far, the implementation of the "strategic infrastructure programme" has deceived: it has been neither quick nor effective as had been originally hoped. In addition, the limited application of the *contraente generale* formula has hindered a sufficient base of case studies from which to draw conclusions about its effectiveness.

The turning point came in May 2006 when a new Government took office as a result of general elections, bringing with it a critical attitude against the pretended advantages of the reforms endorsed by the previous Cabinet, especially focusing on the shortcomings of the *legge obiettivo*.

The main problem is with limited resources. At the end of 2001, the previous Government had approved a long list of 228 strategic infrastructure projects that needed more than 173 billion euros to be implemented but, in fact, only 37 billion had been allocated. Consequently, so far only 19 tenders have been published (involving a total investment of 16.7 billion) and 15 awards to *contraenti generali* have been finalized (at a total expected cost of 13 billion). In only four cases are the works effectively under way, while the largest of all contracts (the realization of the Messina Straight Bridge) has been declared no longer a priority and is waiting for a settlement with the winning consortium, led by Impregilo.

According to many observers, the supposed “new market” shows symptoms of “pathology” similar to the traditional one, which is responsible for the weakness of the Italian civil engineering contractors when compared with most European competitors:

- The “bulimia” of a Government (in power between 2001 and 2006) that announced unrealistic plans and created expectations among the construction industry that could not be satisfied (ANCE 2005).
- The ineffectiveness of the public administration, which has resulted in all sorts of delays. As an example, according to a survey by Ecosfera (2006) on a sample of projects managed under the *legge obiettivo*, the completion of the preliminary designs took an average 671 days instead of the planned 341.
- The lack of selection to the point that 42 subjects already qualify as *contraenti generali*, thus increasing and exacerbating the competitiveness as proved by the fact that the 15 mentioned tenders have been awarded with an average reduction of 12.4% of the prices (for sole construction).

This shows in the economic results. According to *Edilizia e Territorio*’s (Classifiche 2006) annual survey of the balance sheets of the most prominent Italian civil contractors, in 2005 the top 50 groups showed a limited 0.50 profit/turnover index. A more extended Mediobanca (2006) study on the top Italian firms shows that the 2005 turnover increased 1.6% on average mostly due to exports, as domestic activity decreased by 2.1%. Not surprisingly, Impregilo ranks only 25th in the annual listing of the top European groups!

A CASE STUDY

Out of the four projects in actual progress under the *legge obiettivo*, the Sicignano-Atena lot (30 kilometres, see Figure 4 below) of the reconstruction of the Salerno-Reggio Calabria motorway has been the first public work in Italy let out under the new *contraente generale* scheme.

Figure 4: The Sicignano-Atena lot of the Salerno-Reggio Calabria Motorway in southern Italy

The call for bids was published in September 2002, just a month after the mentioned Decree 190 took effect, and the contract was definitely awarded (after a legal settlement) in October 2003 to CMC, the biggest European cooperative construction firm that ranks fourth among Italian contractors.

The awarding authority is Anas, the national agency for roads (and motorways): it agreed to pay CMC 445 million euros (instead of 512.6 as stated in the call for bids), 30% of which was pre-financed by the contractor and reimbursed at the completion of 90% of the work. The duration of the contract was settled in 1.095 days.

The contract basically includes the executive design of the entire project (based on a previous scheme design draw up by Anas in five separated lots), the arrangement of funding for the pre-financing, the executions of the works and the management of the expropriation procedures on behalf of Anas. Figure 5 shows the milestones of the process.

The way this project has so far been managed, starting from the provision of the financial resources, provides interesting insight. A review of the whole process allows us to discover interesting elements and confirms the lack of definition of the contractor's task and responsibility that still marks the Italian *contraente generale* scheme.

As explained by Francesco Francesconi of CMC (Norsa 2007), the first step that his company took was implementing the usual financial scheme. The project, at the level of definition that the design process had reached, was submitted to the corporate sector of a primary Italian bank and presented as a "normal" contract concerning the sole execution of works. The bank understandingly rejected the request. According to Francesconi, this happened because on both sides (bank and contractor) there was insufficient knowledge of the topic: the subject was new to the point that the question had proved inappropriate and inevitably the answer inadequate.

Consequently, a different bank was consulted, with enough experience in *project financing* to appear as a more suitable partner. After careful study, it classified the proposal as “a project-financing scheme without management risk” in which CMC had chosen to avoid the creation of a special purpose vehicle (SPV), which is usual when project financing is at stake.

In this framework, the bank submitted the proposed programme to the due diligence procedures (legal, technical, insurance) typical of the project financing format. As expected, this assessment confirmed that the project could be considered “accepted” by the client only after its final approval. That is, based on a specific clause of the call for bid, two years after the transfer of the completed works to the awarding authority. It means that the intermediate payments connected with partial deliveries do not include any approval by the client.

Consequently, the right to be paid could be pretended by the contractor only after the client final approval, with the obvious risks connected to the possible contract resolution or unconformity of the works.

It needed to devise a financial solution able to limit the contractor’s exposure to this risk, especially about the possible request of reimbursement by the client of all the amount it paid as advance to the contractor, before the final approval.

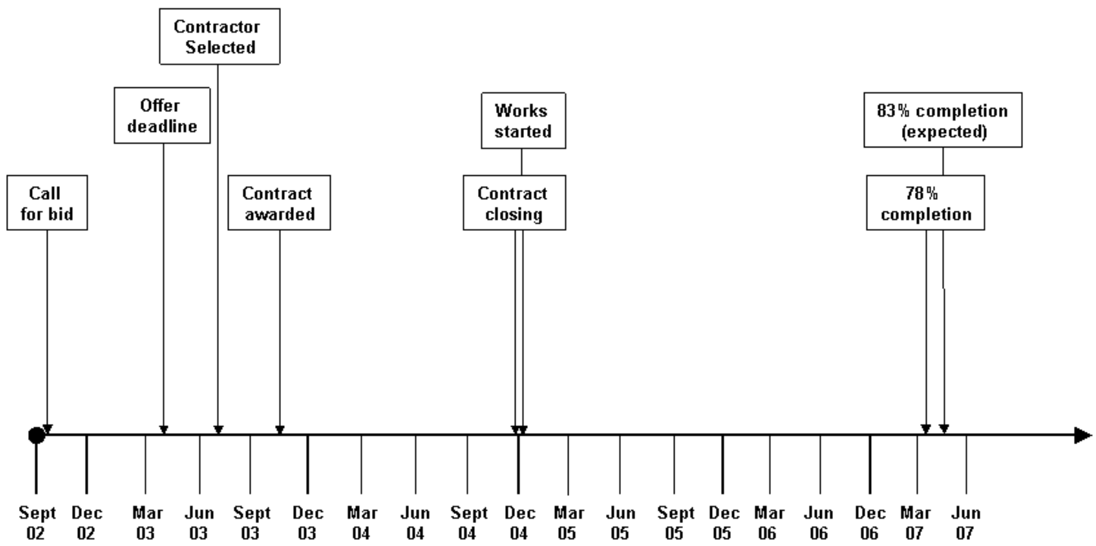


Figure 5: Sicignano-Atena project: the building process milestones

After a long discussion with the bank, a financial scheme was finally identified, but this negotiation postponed the “closing” till December 2004, beyond the deadline (established in 360 days from the project approval) prescribed by the awarding authority for the project kick-off. The latter needed thus a new administrative round to modify the deadline, which caused a further delay and in turns pushed away the slot on which the business plan had been established, with additional modifications to be brought into the business plan and subsequent additional warranty required by the bank.

All this delayed the operation by six months, basically due to the ambiguous nature of the *contraente generale* contract, at least from the bank's point of view, which does not accept to consider such operation like a traditional construction contract because of the relevant financial services included in the contractor package, but interprets it as a sort of "project financing", without operation of the facility but, instead, the need to obtain the pay-back in the shortest period.

CONCLUSIONS

In Italy, the application of the *legge obiettivo* has so far proven controversial. The new scheme was expected to accelerate the construction process in the public works sector and to provide financial resources from the private investors, to lighten the expenditure of public money or, better, to spread it over a long period.

In fact, the contribution of private funding as established by the CG scheme is just a down payment by the contractor to be refunded by the client just before project completion. If not for its greater amount, it is very similar to the bail bond usually request by the client in the classical "general contractor" scheme and is clearly deemed as a guarantee by both the contractors and the banks, as observed in the case study above. Its reimbursement in so short a period cannot produce any substantial effect on the project financial structure, but for the count accounting to be set forward in the annual state budget.

Coupled with an excessive number of projects submitted on this scheme just for "political" reasons (see "The l*egge obiettivo*: is time for an assessment" above), this trick soon revealed its frailty. Moreover, the lack of funding seriously limited the application of the scheme and it hampered gathering any further expected advantage.

In addition, the traditional procedures have not been accelerated in the few cases in which the scheme has been applied, because the variants have revealed several "hidden faults" jeopardizing the effectiveness of the law. And also because –as highlighted above - the CG model has been forced far over the limits of the available resources to a quantity of projects without coherence and without strategic (as well as social) value. (Cipe 2006)

Financial constraints severely limit the application of this law and impose a thorough reassessment of the priorities assigned to the infrastructures that have been announced (and sometimes have already been the object of tenders).

While radically changing this policy, the new Government should focus on the notion of "infrastructure" including both facilities and services, and should therefore inspire its action to two guidelines: liberalization and effectiveness.

As far as the *contraente generale* system of procurement is concerned, some specific suggestions can be made on a technical ground according to the state of the art as it has been previously sketched.

First of all it must be recognized that whenever a public client requires "pre-financing" from a bidder, it is an obvious case of the PPP scheme in which PPP should extend to the phase immediately following construction, i.e. operation of the facility. This seems essential to not only assure that quality is delivered and monitored but also that the contractor has a larger (and longer) payment on which to rely in order to make pre-financing "bankable". This is especially advisable if Italy wants to favour the growth of few general contractors large (and strong) enough to compete with counterparts from other European countries. In this aim, it is essential that Italian public clients improve their management skills, considering that "a strong demand is a prerequisite for a strong offer" (Norsa 2005)

To implement any approach of public private partnership, contracting authorities must resort to the services of professional PCM to help them govern the whole process. Contractors must do the same, as their internal management skills can rarely match those of professional organizations.

This is not only a guarantee that the works are delivered in time, at cost and with quality satisfying the performance requirements, but also needed to accelerate the evolution of the construction market to an essential component of the "service economy" where private partners offering both capital and managerial skills can thrive.

REFERENCES

– (2006) Speciale Classifiche - Le prime 50 società italiane. *Edilizia e Territorio*, **46** (suppl.).

ANCE and AGI (2005) *Rapporto sulle infrastrutture in Italia*. Rome: Edilstampa.

Bougrain, F, Carassus, J and Colombard-Prout, M *et al*. (2005) *Partenariat public privé et bâtiment en Europe: quels enseignements pour la France? Retour d'expériences du Royaume-Uni, d'Italie, du Danemark et de France*. Paris: Presses de l'École Nationale des Ponts et Chaussées.

Cipe (2006) *Esiti del tavolo di ricognizione sullo stato di attuazione della legge obiettivo*. Rome: Cipe.

EC directive 93/37, and now also Directive 2004/18/EC on the coordination of procedures for the award of public works, supplies and services contracts.

Ecosfera (2006) *Le infrastrutture strategiche in Italia*. Rome.

Mastermann, J W E (2002) *Introduction to Building Procurement Systems*. 2ed. London: Spon Press.

Mediobanca (2006) *Le principali società italiane*. Milan: Mediobanca.

Norsa, A (Ed.) (2005) *La gestione del costruire tra progetto, processo e contratti*. Milan: FrancoAngeli.

Norsa, A (Ed.) (2007) *Nuova Finanza per le infrastrutture. Atti del Seminario, Roma, Ottobre 2006*. Milan: Guamari.

Norsa, A and Antonini, E (2006) General contracting versus PCM: the Italian way. *In:* R Pietroforte, E De Angelis and F Polverino (Eds.) *Construction in the XXI Century-Local and Global Challanges- Proceedings of Joint 2006 CIB W65/W055/W086 Symposium*. Naples: Esi-Edizioni Scientifiche Italiane.

Perry, J C (1985) *The Development of Contract Strategies for Construction Projects*. Manchester: University of Manchester

A SYSTEMS APPROACH TO SUPPLY CHAIN INTEGRATION IN CONSTRUCTION

Ruben Vrijhoef[1] and Hennes de Ridder

Delft University of Technology, Faculty of Civil Engineering, Department of Building Processes, PO Box 5048, NL-2600 GA Delft, The Netherlands.

By nature, construction has been dominated by project-based production, involving relatively many independent firms joining in constantly changing one-off coalitions. As a consequence, the construction supply chain is relatively fragmented, the production environment is relatively unstable, and as a result, the industry performance has been low, particularly compared to other industries. Application of supply chain integration has been deemed as a major solution to resolve many problems of construction. This may concern client-led integration strategies, as well as supplier-led integration strategies. A systems approach could help to build a model of supply chain integration to enable construction parties to develop repetitive and integrated strategies in the supply chain. When applying a systems approach, the supply chain must be viewed, engineered and built as a 'systems of systems'. In order to build this model eventually, the work presented applies the ideas of 'management research as a design science' and 'constructive research', rather than 'analytical research'. First, a generic model will be built applying 'theoretical 'building blocks' from four theoretical perspectives: economic, social, organizational and production system. Next, the generic model will be specified and validated by adding empirical 'building blocks', i.e. practical examples of supply chain integration inside and outside construction, and thus confronting the generic model with practice. The result will be tested and generalized by inviting expert opinions about the general validity and capabilities of the model to actually help building construction supply chains as integrated systems. The work will result in a set of guidelines for different parties in the construction supply chain to shift from a project-based approach towards a repetitive approach to their business. On an inter-firm scale, this must lead to a move from project delivery by occasional coalitions of dispersed firms towards integrated product development within 'extended enterprises' of aligned firms.

Keywords: construction, integration, modelling, supply chain, systems engineering.

INTRODUCTION

In construction, the production system, and the supply chain in particular, have been deemed to be disintegrated and inefficient. A more integrated approach to construction has been coined very often as a solution for the many problems and deficiencies existing in construction. On the other hand also the restrictions of integration in construction have often been discussed, because of the temporary nature and dispersed structure of the industry.

In essence, construction can be typified as a specific kind of project-based industry dominated by a project-based and capability-oriented production system. The construction process has been observed as a make-to-order, design-to-order, or even concept-to-order kind of delivery process (Winch 2003). The industry mainly delivers

[1] r.vrijhoef@tudelft.nl

one-off engineer-to-order products (ETO), rather than repetitive assemble-to-order (ATO), make-to-order (MTO), or make-to-stock (MTS) products as delivered by manufacturing types of production systems (Wortmann 1992). Both types of systems are fundamentally different, and 'treating construction as a type of manufacturing obviously neglects design, and arguably subordinates value generation to waste reduction, which inverts their proper relationship'. However, 'certain aspects of construction should move into the realm of repetitive making' (Ballard 2005). Production system types of different industries could be dominated by either (one-off) designing or (repetitive) making (Figure 1).

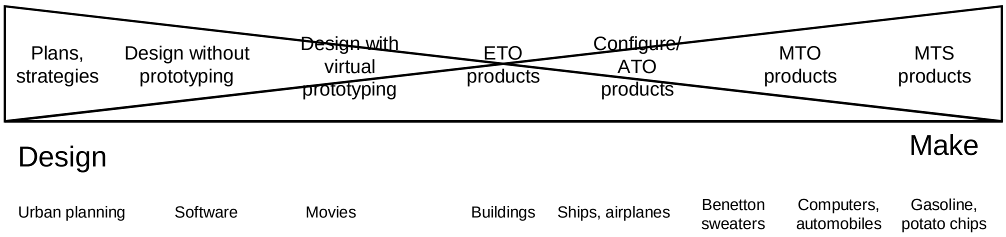


Figure 1: Production system types (Ballard 2005)

The fact that construction is predominantly a demand-driven process and design is often disconnected from production leads to various problems of production. The producer is not the designer, and production is mostly based on craftsmanship mainly taking place outdoors. Moreover production involves many crafts and relatively small firms. This causes problems originating upstream the supply chain to persist and often become worse downstream, because of the mechanisms of causality and interdependence within the supply chain.

This notion leads to the main idea of the work presented aimed at the development of a model for integrated construction supply chains. This touches on the basic peculiarities of construction as a disintegrated industry, and the negative effects of this on the performance of the construction supply chain. The premise here is that the construction supply chain would function better when approached and (re)built as a single entity, an extended enterprise. In a way, the broader issue here is whether construction could or should develop itself towards the standards and practices of a 'normal', more integrated, supply-driven industry.

In contrast to most previous construction management research, this research explicitly aims to build a multi-theoretical and multi-aspect model and guidelines to enable the integration of multiple firms and repetition of multiple projects. This paper gives an overview of the status of the research that is currently underway. In particular, the paper gives an insight into the 'building blocks' found in theory and practice, to be used in the process of model building further on in the research.

VIEWING THE SUPPLY CHAIN AS A SYSTEM

Systems theory views the world in terms of collections of resources and processes that exist to meet subordinate goals. Two aspects of systems theory are of particular importance for supply chains: synergy and entropy. Synergy means the parts of a system working together can achieve more than the sum of achievements that each one would achieve separately. Entropy refers to the necessity of feedback across the chain to prevent debilitation of the system (New and Westbrook 2004). Hassan (2006) suggested the application of system engineering to the design and formation of supply chains. The structurist character of systems thinking can be helpful building the structure and operations of the supply chain in a systematic manner, ensuring its effective functioning.

In terms of systems typology, supply chains are human activity systems and social systems, consisting of actions performed by individuals and groups of individuals, i.e. firms (Checkland 1981). Supply chains can be characterized as networks between economic actors (e.g. firms), engaged in a voluntary relationship to produce and deliver a product or service. Rouse (2005) considers the nature of firms as systems, and supply chains as 'systems of systems'. This is essential to fully understand and thus be able to find integrated solutions to improve firms and systems of firms (i.e. supply chains). Rigby *et al.* (2000) underline the importance of systems thinking for organizational change and improvement, but warn of the risk of underestimation of the complexity of reality when translating this reality into a mental model. Systems approaches are not fully capable of capturing 'soft factors' such as power, trust and human factors.

UNDERSTANDING THE CONSTRUCTION SUPPLY CHAIN

Industry structure

Often the construction industry has been characterized by complexity, referring to the demography of the industry (many SMEs and specialist firms) and the organization of construction, including the configuration and coordination of construction supply chains. Indeed construction as such is a less structured industry compared to other industries, with a vast network of actors of different kinds around a project, i.e. the development and construction of a built object (Figure 2).

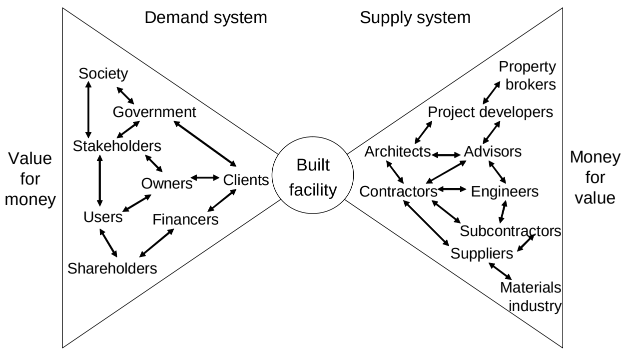


Figure 2: Demand and supply systems in construction (Vrijhoef and De Ridder 2005)

Make-to-order delivery and craftsmanship

Construction supply chains are make-to-order supply chains, where project management and engineering are important issues. The fact that construction is often a demand-driven make-to-order process and design is often disconnected from production leads to various problems of production. The producer is not the designer, and production is very much influenced by craftsmanship. Moreover production involves many crafts and many relatively small firms. This causes problems originating upstream the supply chain to persist and often become worse downstream, because of the mechanisms of causality and interdependence within the supply chain.

One-of-kind and onsite production

Most production in construction is one-off and done on site. The 'factory' is organized on site, and mostly very few materials and components of the end products are prefabricated or preinstalled off site. The logistics in construction are converging, meaning relatively many suppliers are directly involved for the production of an end product for one or very few customers. On the other hand, buildings are physically, economically and socially linked with their environment in terms of use of space and surface, availability of resources and capital, local design and construction practices.

Role of the client and user

In most construction projects the end-customer is at the start as well as the end of the entire process, and therefore the customer and end-users play a dominant role in construction. This also causes the make-to-order mechanism and the need for reactivity in construction supply chains. This is the reason why in construction products are rarely ‘launched’ and ‘marketed’ as in other industries, and why construction is different from most other industries, e.g. consumer goods. Most contractors are not manufacturers of integrated end-products. Most products are not standard, and processes are not repetitive, and often cause high levels of waste (Vrijhoef and Koskela 2000).

AIMS OF SUPPLY CHAIN SYSTEMS ENGINEERING

Supply chain integration as a goal of supply chain systems engineering

One can understand that low levels of integration and repetitiveness in construction lead to problems and underperformance of the construction supply chain as a production system (e.g. Vrijhoef and Koskela 2000). One way of resolving this is to apply concepts that increase integration and repetition within and between project supply chains, such as in partnering arrangements (e.g. Bresnen and Marshall 2000). Previous work points out the need for more alignment and more structured ways of working in the construction supply chain. Systems engineering can help in a sense that systems engineering’s goal here is supply chain integration, and to ‘engineer problems out’ of the supply chain, i.e. the production system (Hassan 2006).

Improving the supply chain by supply chain integration

Stevens (1989) points out the importance and possibilities of supply chain integration for companies to react to market conditions and reduce cost levels. In order to do so, ‘virtually all firms and functions’ in the supply chain should be connected, operating as it were a ‘factory without walls’. However, in many cases, it is simply impossible to fully integrate an entire supply chain (Fawcett and Magnan 2002). This is particularly true for temporary and fairly disintegrated construction supply chains.

This also means supply chain integration can contribute substantially to the overall performance improvement of construction, enabling the industry to deal with the diversity of demand, and reduce the instability of the production environment. It also improves the efficient integration of construction inputs and new technologies, and harnesses the delivery process against the impact of economic and social turbulence. This more centralized mode of process control calls for central roles to be played by the supply chain: the system integrator. This role could be divided in two partial roles: the demand system integrator and the supply system integrator (Figure 3). For instance the client organization responsible for the procurement could take up the demand integrator role; the main or prime contractor could take up the supply integrator role (Vrijhoef and De Ridder 2005).

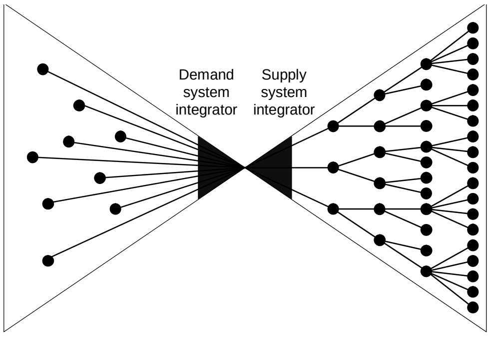


Figure 3: The role of the demand and supply system integrator (Vrijhoef and De Ridder 2005)

RESEARCH APPROACH

The research presented follows the ideas of theory building from case studies as introduced by Eisenhardt (1989). The approach is semi-inductive starting from theory and case studies (building blocks), shaping hypotheses, and from there building a theory (model). This corresponds with the ideas of 'constructive research', which combines the analysis of existing phenomena and building new concepts at the same time. This kind of research is aimed at designing 'solution-oriented research products', rather than deducing 'analysis-based explanations', while viewing management research as design (or engineering) science (Van Aken 2005).

The research approach could be summarized as an engineering approach, i.e. engineering a supply chain integration model as if it were a system that should be functional and useful. This engineering process starts by building the generic supply chain integration model using the theoretical 'building blocks' found in the four theoretical perspectives presented below: social, economic, organizational and production. The generic model built from the theoretical building blocks will next be validated by confronting it with empirical evidence from case studies of supply chain integration, outside and inside construction.

In the research, the case studies within construction aim at describing the supply chain integration strategies applied by different parties, i.e. firms along the construction supply chain, e.g. clients, architects, contractors and suppliers. The case studies cover a number of types of construction rather than one specific type of construction. In a later phase of the research, guidelines for supply chain integration for different types of construction are derived from the model, based on the discussion of the case study analysis results with experts.

THEORETICAL BUILDING BLOCKS

Supply chain viewed as a social system

In construction the relations between firms are typically maintained for the duration of the project. Supply chains are directed not merely towards minimizing transaction costs, but also towards enhancing the transfer of expertise and systematic feedback on planning, design, construction and maintenance between parties, and ultimately towards striving for joint value maximization. Increased cooperation and integration between supply chain parties enables delivery of a total product with quality guarantees to the market. Bounded rationality and differences in know-how between firms would be resolved by joint product development. Opportunistic behaviour is then replaced by mutual trust, which obviously is necessarily for an open dialogue (language) and optimal knowledge sharing.

On an industry scale, Dubois and Gadde (2002) distinguish tight couplings in individual couplings in projects and loose couplings in the permanent network within the industry as a 'loosely coupled system'. The pattern of couplings influences productivity and innovation, and the behaviour of firms. In terms of organizational behaviour, cultural and human issues such as trust and learning have been indicated as having major implications for construction supply chains (Love *et al*. 2002). The social systems approach therefore lays the socio-organizational basis for improved inter-firm relationships within the supply chain.

Supply chain viewed as an economic system
In economic terms a supply chain is a series of economic actors, i.e. firms buying from and selling to each other. From an economic perspective the choice of a coordination mechanism or governance structure is made by economizing on the total sum of production and transaction costs (Williamson 1979). Transaction cost economics (TCE) provides an explanation for the existence and structure of firms and for the nature of coordination within a supply chain (Hobbs 1996). When transaction costs are low, contracting is used (i.e. market structure), while internalization will prevail for high transaction costs (i.e. hierarchy). Intermediate modes are often referred to as hybrid modes (Williamson 1991).

TCE recognizes that transactions do not occur without friction. Costs arise from the interaction between and within firms as transaction costs: information costs, negotiating costs and monitoring costs (enforcement costs) (Hobbs 1996). Transaction costs would be zero if humans were honest and possessed unbounded rationality. Transaction costs for a particular transaction depend on the three critical dimensions of transactions: asset specificity, uncertainty and frequency (Williamson 1985). Besides these key concepts underpinning TCE (bounded rationality, opportunism, asset specificity, uncertainty and frequency), Milgrom and Roberts (1992) add two other items: difficulty of performance measurement, and connectedness to other transactions. Both are relevant from a supply chain viewpoint, and influence the possibilities to reduce transaction costs. Obviously improved collaboration and communication in the supply chain will reduce transaction costs.

Supply chain viewed as a production system
The supply chain is aimed at the delivery of a product or service to an end market or a single customer. This implies a production process which is purposive. The management of the production process needs to ensure the purpose of the process is achieved effectively and efficiently by addressing the transformation (conversion), flow and value aspects of production in an integrated manner (Koskela 2000). In terms of the firm, both primary and support activities are aimed at the delivery of customer value, and as a result revenues and profit for the firm (Porter 1985) (Figure 4).

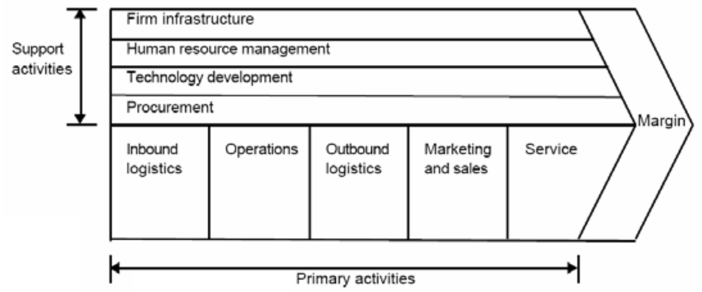


Figure 4: Value chain (Porter 1985)

Supply chain viewed as an organizational system

Firms as well as supply chains are organizational systems built from various vital elements that make them function as they do. By viewing organizations as systems of flows, Mintzberg (1979) identifies four system representations of organizations together making up the structure and infrastructure of organizations: the organization as a system of formal authority, regulated flows (material, information), informal communication, work constellations and ad hoc decision processes.

Typically, the supply chain is a ‘system of systems’, or a ‘superstructure’ of organizations. Firms along the supply chain perform distributed production activities and business functions. This raises the issue of core competences of firms (Prahalad and Hamel 1990), together making up an ‘extended enterprise’. In construction this relates to the idea of the ‘quasi-firm’ coined by Eccles (1981).

EMPERICAL BUILDING BLOCKS

Based on the theoretical building blocks, first a generic supply chain integration model will be built. The generic model will next be specified and validated by adding empirical ‘building blocks’ from a few case studies of supply chain integration outside and inside construction. These case studies include multiple cases including the four cases below, i.e. two companies outside construction (truck manufacture and shipbuilding), and two construction firms (housing and commercial building). For reasons of limited space in this paper, below the four cases are described very briefly.

Two examples of supply chain integration outside construction: truck manufacture and shipbuilding

In the early 1990s the Dutch truck industry went into a crisis. After drastic reforms most companies recovered, and are currently doing quite well. One of the measures was to reform and integrate the supply chain. Suppliers have been integrated in product development, planning and logistics. In respect of the clients, in Europe, an integrated dealer network has been established, which ensures direct follow-up of defects to trucks, and 24-hour on-road maintenance.

In the Dutch shipbuilding industry, a few producers have improved their businesses drastically. They are globally leading companies in limited product categories. For those products they have introduced strict standardization and modularization, and imposed this on their suppliers. This has improved the profitability and quality dramatically. Some suppliers have become ‘external business’ units, guaranteeing the close links.

Two examples of supply chain integration inside construction: housing and commercial building

In the Dutch housing sector, a few builders have transformed their business and become suppliers of completely pre-engineered houses. They deliver houses from their catalogues to be built in one week. The different types of houses can be customized completely according to clients' wishes. The fully integrated in-house production and pre-installation of the houses ensure a smooth process, and prevent delays and quality problems. In addition to the delivery of the house itself, they arrange for the permissions from local governments, mortgage and other additional issues.

In the Netherlands, many project developers have moved their business towards the 'front end' of the supply chain. They have acquired land and existing buildings to be developed and redeveloped. Additionally they deliver all services desired by their clients including finances, maintenance, facility management and operations such as security and restaurants of offices. Some project developers have integrated the supply chain to such an extent that they actually became their own clients, in order to find users of their projects after completion.

Comparing supply chain integration outside and inside construction

When broadly comparing the examples of supply chain integration inside and outside construction, one sees differences as well as similarities. Differences can be found in the possibilities to pre-engineer products, and integrate the supply chain. Outside construction the levels of pre-engineering and integration are higher, because levels of repetition are generally higher. Similarities can be found in the mechanisms to integrate design, follow up clients, and offer additional services to clients. Apparently these issues are generally valid and play a role in most industrial sectors delivering products to customers.

However, the characteristics of industries vary from industry to industry. The production system of each industry has been shaped by the industry characteristics and history. Project production systems in project-based industries such as construction are aimed at a product mix that is 'one of a kind or few', process patterns are 'very jumbled', processes segments are 'loosely linked', and management challenges are dominated by 'bidding, delivery, product design flexibility, scheduling, materials handling and shifting bottlenecks' (Schmenner 1993). The fragmentation of the construction industry has been identified for decades as a major point of the complaints about the state of practice (Turin 2003), reflected most characteristically by the predominant one-off approach in construction projects, or 'unique-product' production (Drucker 1963).

IMPLICATIONS OF SUPPLY CHAIN INTEGRATION

Implications from a demand system perspective

Traditionally, clients have played an important and dominant role in construction (Cherns and Bryant 1984). Also with regard to supply chain integration, the client's role can be rather critical, while he makes the initial decision to procure construction works and the way in which procurement takes place (Briscoe *et al*. 2004). Clients who have the power to shift their procurement strategies vis-à-vis the market are in a position to align the supply chain effectively, and implement supply chain integration successfully (Cox and Ireland 2001). In these cases, procurement strategies must therefore be aimed at establishing long-term relationships in the supply chain. Some advanced and professional clients with 'buying power' have created multi-project environments and manage their procurement through a portfolio approach (Figure 5), aimed at the increase of repetition and creating similarities between multiple projects, and thus increasing the degree of project certainty and 'supply chain stability' (Blismas *et al*. 2004). Often these clients have successfully introduced a strategic long-term approach to procurement, which has proved to be particularly effective for certain sectors in construction (Cox and Townsend 1998).

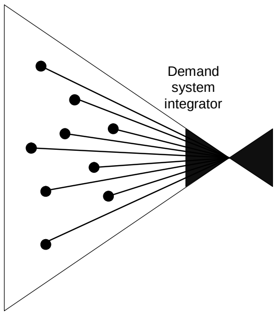


Figure 5: The role of the demand system integrator (Vrijhoef and De Ridder 2005)

Implications from a supply system perspective

On the supply side, parties have evolved towards more integrated arrangements through project-independent collaboration with other parties in the supply chain as well as internalization of neighbouring activities or businesses. In both cases operational and competitive advantages, through higher levels of productivity and efficiency as well as delivering better client value are the drivers for this kind of supply chain integration. Normally this development is led by a focal firm, the system integrator; this could be a main contractor, but also an architect or engineering firm (Figure 6).

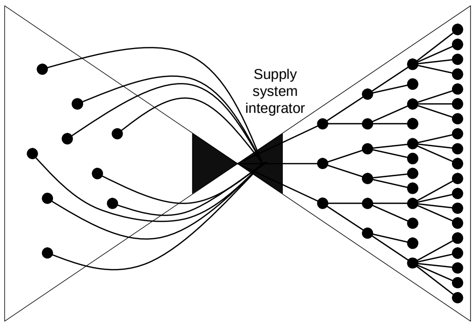


Figure 6: The role of the supply system integrator (Vrijhoef and De Ridder 2005)

CONCLUSIONS

Theory as well as examples from other industries claim and demonstrate the value of supply chain integration. This is also true for construction. Owing to the characteristics of construction, a specific model for supply chain integration in construction must be adapted and built, including guidelines for firms along the supply chain in different types of construction. A systems approach as proposed in this research is helpful to build the integration model and improve construction supply chains. This exercise includes a 'building exercise' using theoretical building blocks (concepts) and empirical buildings blocks (cases) leading to a 'change model' of 'organizational rebuilding' of existing construction supply chains. In order to do so all functions along a supply chain in fact need to be deconstructed, followed by reconfiguration of the functions and the interfaces between these functions. By doing this, the endemic problems and irrationalities should be 'engineered out' of the construction supply chain, eliminating existing problems including their negative symptoms. The side effect must be that the control of different functions will get more aligned and centralized, transforming the supply chain into an integrated structure, i.e. extended enterprise.

Although the application of supply chain integration to construction is a fundamental and potentially strong solution to improve the performance of construction practice, the take-up by the industry is not widespread. Apparently, the possibilities in construction are restricted compared to other industries. This includes the possibilities for product development, standardization and prefabrication, and achieving economies of scale for a large market. These characteristics are the main reasons why supply chain integration in construction has been slow, and thus needs intelligent solutions.

REFERENCES

Ballard, G (2005) Construction: one type of project-based production system. *In*: *Proceedings SCRI Forum Event Lean Construction: The Next Generation*, 19 January 2005, Salford, SCRI, University of Salford, 14.

Blismas, N, Sher, W, Thorpe, A and Baldwin, A (2004) A typology for clients' multi-project environments. *Construction Management and Economics*, **22**, 357–71.

Bresnen, M and Marshall, N (2000) Building partnerships: case studies of client–contractor collaboration in the UK construction industry. *Construction Management and Economics*, **18**, 819–32.

Briscoe, G H, Dainty, A R J, Millett, S J and Neale, R H (2004) Client-led strategies for construction supply chain improvement. *Construction Management and Economics*, **22**(2), 193–201.

Checkland, P (1981) *Systems thinking, systems practice*. New York: John Wiley & Sons.

Cherns, A B and Bryant, D T (1984) Studying the client's role in construction management. *Construction Management and Economics*, **2**, 177–84.

Cox, A and Ireland, P (2001) Managing construction supply chains: the common sense approach for project-based procurement. *In*: *Proceedings 10th International Annual IPSERA Conference*, 201–13.

Cox, A and Townsend, M (1998) *Strategic procurement in construction: towards better practice in the management of construction supply chains*. London: Telford.

Drucker, P F (1963) *The practice of management*. London: Heinemann.

Dubois, A and Gadde, L E (2002) The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management and Economics*, **20**, 621–31.

Eccles, R G (1981) The quasi-firm in the construction industry. *Journal of Economic Behavior and Organization*, **2**(4), 335–57.

Eisenhardt, K M (1989) Building theories from case study research. *Academy of Management Review*, **14**(4), 532–50.

Fawcett, S E and Magnan, G M (2002) The rhetoric and reality of supply chain integration. *International Journal of Physical Distribution & Logistics Management*, **32**(5), 339–61.

Hassan, M M D (2006) Engineering supply chains as systems. *System Engineering*, **9**(1), 73–89.

Hobbs, J E (1996) A transaction cost approach to supply chain management. *Supply Chain Management*, **2**(1), 15–27.

Koskela, L (2000) An exploration towards a production theory and its application to construction. VTT Publications 408, VTT, Espoo.

Love, P E D, Irani, Z, Cheng, E and Li, H (2002) A model for supporting inter-organizational relations in the supply chain. *Engineering, Construction and Architectural Management*, **1**(9).

Milgrom, P and Roberts, J (1992) *Economics, organization, and management*. Englewood Cliffs, NJ: Prentice Hall.

Mintzberg, H (1979) *The structuring of organizations: a synthesis of the research*. Englewood Cliffs, NJ: Prentice Hall.

New, S and Westbrook, R (Eds.) (2004) *Understanding supply chains: concepts, critiques and futures*. Oxford: Oxford University Press.

Porter, M E (1985) *Competitive advantage*. New York: Free Press.

Prahalad, C K and Hamel, G (1990) The core competence of the corporation. *Harvard Business Review*, May–June, 79–91.

Rigby, C, Day, M, Forrester, P and Burnett, J (2000) Agile supply: rethinking systems thinking, systems practice. *International Journal of Agile Management Systems*, **2**(3), 178–86.

Rouse, W B (2005) Enterprises as systems: essential challenges and approaches to transformation. *System Engineering*, **8**(2), 138–50.

Schmenner, R W (1993) *Production/operations management: from the inside out*. New York: Macmillan.

Stevens, J (1989) Integrating the supply chain. *International Journal of Physical Distribution and Materials Management*, **19**(8), 3–8.

Turin, D A (2003) Building as a process. *Building Research & Information*, **31**(2), 180–7.

Van Aken, J E (2005) Management research as a design science: articulating the research products of mode 2 knowledge production in management. *British Journal of Management*, **16**, 19–36.

Vrijhoef, R and De Ridder, H (2005) Supply chain integration for achieving best value for construction clients: client-driven versus supplier-driven integration. Paper presented at QUT Research Week, 4–6 July 2005, Brisbane.

Vrijhoef, R and Koskela, L (2000) The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management*, **6**(3–4), 169–78.

Vrijhoef, R, Koskela, L and Voordijk, H (2003) Understanding construction supply chains: a multiple theoretical approach to inter-organizational relationships in construction. Paper presented at the 11th Annual Lean Construction Conference (IGLC-11), 22–24 July 2003, Blacksburg.

Williamson, O E (1979) Transaction-cost economics: the governance of contractual relations. *Journal of Law and Economics*, **22**, 233–61.

Williamson, O E (1985) *The economic institutions of capitalism: firms, markets, relational contracting*. New York: Free Press.

Williamson, O E (1991) Comparative economic organization: the analysis of discrete structural alternatives. *Administrative Science Quarterly*, **36**(2), 269–96.

Winch, G M (2003) Models of manufacturing construction process: the genesis of re-engineering construction. *Building Research & Information*, **31**(2), 107–18.

Wortmann, J C (1992) Production management systems for one-of-a-kind products. *Computers in Industry*, **19**, 79–88.

RELATIONSHIP MANAGEMENT: A CASE STUDY OF KEY ACCOUNT MANAGEMENT IN A LARGE CONTRACTOR

Hedley Smyth[1] and Tim Fitch

The Bartlett School of Graduate Studies, University College London, (Torrington Place Site), Gower Street, London, WC1E 6BT, UK

Relationship management theoretically arises from relationship marketing, which includes key account management (KAM) as a concept. Relationship management is distinct from relational contracting, which induces behaviour derived from changes in market structure, whereas relationship management is behaviourally proactive. The main relationship marketing tenets are provided, showing development into relationship management, specifically in construction. Relationship management has been partially applied in construction. However, several large contractors are applying elements. Investment and resource allocation, and organizational behaviour have posed constraints, particularly concerning service continuity in construction. In construction particular issues are posed at the project-corporate interface, requiring contractors to become more interventionist, along the lines of portfolio management, especially for KAM, which is explored through an in-depth case study of a major UK contractor as it is being implemented. The method combines external observation with action research. Emphasis is placed upon analysing the KAM concept contextually, in terms of both projects and behaviour in the form of individual and organizational behaviour in order to explore causality in practice from the formation and implementation of the policy.

Keywords: management of the firm, marketing, organizational behaviour, relational contracting.

INTRODUCTION

Enterprise management has moved towards emphasizing process management above structure over the last 20 years. Construction has made some moves away from adversarial behaviour towards more collaborative practices. There remains a primary emphasis upon structural approaches to the market (Smyth 2006), which includes relational contracting. A relationship approach is process-orientated approach. Relationship marketing and management are therefore process-orientated (Pryke and Smyth 2006). A concept of relationship management is the key account handler (KAM), which seeks service improvement for the client, and repeat business for the contractor from having a single role responsible for client management.

The *aim* of this paper is to explore the concept and application of KAM in construction. The *objectives* are to locate KAM within relationship marketing, examining how this has been developed in theory and practice into relationship management (RM) in construction. A further objective is to clarify the distinction between relationship management and relational contracting (RC). The final objective

[1] h.smyth@ucl.ac.uk

is to explore how relationship marketing and management are being applied in a leading construction firm.

The findings in general terms add support for the *relationship paradigm* concerning the Management of Projects (MoPs) (Smyth and Morris, 2007; Pryke and Smyth, 2006). The findings specifically add support for the application of RM in construction, hence demonstrating in practice differences between RM and RC, which is of normative significance because adherence to the concept RC has imposed artificial constraints upon the scope for developing firm and project management in construction practice (see Table 1). More specifically, KAM is shown to provide a means to address one considerable obstacle to increased client satisfaction on the one hand, and deliberate and differentiated service delivery by contractors on the other hand, by addressing consistency and continuity of service on projects and programmes.

Table 1: Features of relational contracting and relationship management

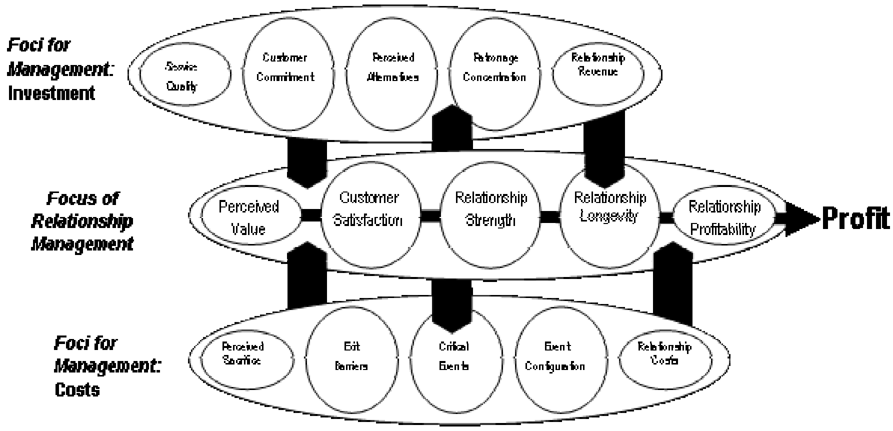
Relational Contracting (RC)	**Relationship Management (RM)**
Market driven	Organizationally driven
Structural change to induce behavioural change	Process changes to improve performance and induce structural change
Governance through client procurement requirements	Aggregated behaviour through contractor strategic choice
Top down	Bottom up
Contractor reactive	Contractor proactive
Project commitment	Corporate commitment across projects
Low investment	High investment
Ability to move from Relational Contracting to Relationship Management	

RELATIONSHIP MARKETING AND RELATIONSHIP MANAGEMENT

In marketing, there has been a *paradigm* shift since the mid-1980s from the transaction approach of the marketing mix towards a proactive paradigm of human agency called relationship marketing, in essence a way to restore the sole trader-customer relationship for large organizations through strategy and systems. The marketing mix paradigm was seen as appropriate for mass-market consumer goods, whilst relationship marketing was increasingly perceived to be appropriate for business-to-business transactions, especially for intangible services. Dominant schools of thought have had different emphases, for example the pioneering Nordic School (e.g. Grönroos 2000; Gummesson 2001), the founders of the largely Anglo-Saxon IMP Group (e.g. Christopher *et al*. 2001; Ford *et al*. 2003) and the more pragmatic North American stream (e.g. Berry *et al*. 1983; Reichheld 1996), common themes being investment in and value from relationships (Ford *et al*. 2003), and a market orientation pursued through networks of relationships (Gummesson 2001). The business purposes typically included:

- Increasing customer loyalty, hence relationship strength and longevity by increasing customer satisfaction.
- Increasing profitability through adding relationship and service value, and reducing sales plus other transaction costs.

Concepts and practice have broadened since the beginning with relationship marketing being perceived as both an alternative as well as being complementary to the marketing mix (Kotler *et al*. 1996). Developing relationship marketing requires a range of conceptual tools. For example, Gummesson (2001) identified 30 different types of relationship within four categories that required management, and Storbacka *et al*. (1994) developed a model to guide its management (Figure 1).



.

Figure 1: A simplified model of relationship management (Source: Pryke and Smyth 2006, adapted from Storbacka *et al*. 1994)

In order to deliver customer satisfaction, it was quickly recognized that managing relationships required actions that went beyond marketing. Gummesson (2001) asserted everyone was a part-time marketer and some organizations eliminated marketing departments in response. Relationship marketing was developed into a management approach for what were complex, intangible services that operated in uncertain and high-risk contexts (cf. asset specificity and bounded rationality in transaction cost terms). Hence, relationship management was developed, as implied within Figure 1.

Managing critical events, sometimes called *moments of truth*, at the customer-supplier interface and with other stakeholders is important. A management tools to address this issue is the concept of the key account manager (KAM) (e.g. McDonald *et al*. 1997; Kempeners and van der Hart 1999). Having a primary single point of contact, the KAM, permits the supplier to provide consistency and continuity of service. Applying the KAM concept within RM needs clarity and precision. The transactional approach of marketing mix manages sales through a single point of contact, sometimes depicted as a butterfly or bowtie diagram with sales and procurement being the primary economic interface, whereas RM is multi-faceted and cross-functional, recognizing a series of interfaces (Figure 2). In order to ensure consistency over a series of transactions and continuity for service delivery, a KAM manager acts as the internal manager to muster the service across the supplier interface with the customer, who preferably identifies a counterpart in order to improve collaboration.

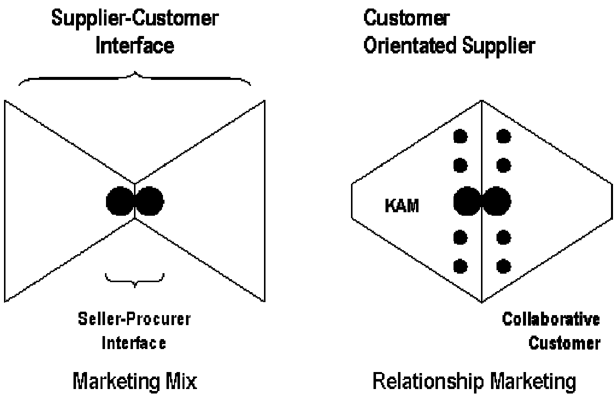


Figure 2: Customer interfaces and the location of KAM

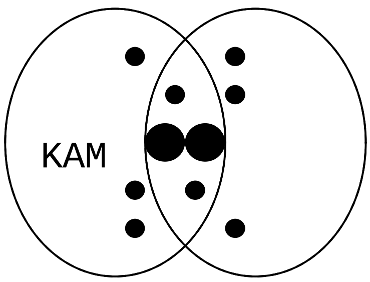


Figure 3: KAM within a network of transaction relationships

Initial contact may be transactional; developing into RC as relationships develop, it can transition into relationship marketing, then RM, the boundaries of the firms becoming less distinct behaviourally – a more organic network of relationships (Figure 3). Those personnel located within the overlap have intensive contact and constitute the decision making unit (Smyth 2000). To work consistently, RM becomes embedded as a core competency (cf. Pralahad and Hamel 1990), hence as social capital, which has the feature of appreciating with use, unlike most financial assets, as well as being a set of business systems. Implicit in the KAM concept within relationship marketing is the notion that some accounts are non-key, thus key accounts will tend to constitute the core business in volume in relation to service expertise (e.g. McDonald *et al*. 1997; Spencer 1999; Ojasalo 2001) and/or non-key customers are managed transactionally; however, in firms adopting RM all customers are considered key for the business unit or company.

The introduction of KAM can increase transaction costs, however, any increase is conceptually offset through efficiencies in sales costs as a result of repeat business, efficiency through effective learning and productive responses made through relationship strength and longevity, and by profits derived from added relationship, hence service value. RM generally and KAM specifically provides a focus for collaborative working, such as partnering and SCM, but this again raises issues concerning a further raft of investment, costs and returns.

RM requires resources to be allocated for investment in the strategy and systems for operation and in the norms (organizational culture) and codes of conduct as a core competency within the resource base view (Barney 2003). However, a conceptual distinction has to be made between RC as a branch of transaction cost theory and RM as a competency for inducing more cooperative forms of behaviour. RC is a top-down approach with a reactive response in behaviour hence action. RM is bottom-up, proactively soliciting behavioural changes in aggregate behaviour. Once a significant number of firms engage with this, there is opportunity to change governance and market structure. Changes in market structure are likely to be seen as greater differentiation of services and therefore increased numbers market segments defined by service configurations – ultimately to segments of one firm in idealized terms (Gummesson 2001; Smyth 2000 in construction). Relationships can be developed to a more sophisticated level and actively managed within RM in ways that go beyond RC, although RC can act as a basis for transitioning into RM (Smyth and Edkins 2007).

This section has set out the main tenets of relationship marketing and RM, and the KAM concept. The distinction between RM and RC has also been made.

APPLICATION IN THE CONSTRUCTION FIRM

Relationship marketing is more theoretically aligned than the marketing mix to most of the characteristics of construction and contractors (Smyth 2000, 2006). However, practice does not support this conceptual proposition to date, a primary reason being the tendency to minimize investment and transaction costs in lumpy and uncertain markets where individual firms lack market dominance and leverage with clients and their customers (Gruneberg and Ive 2000; Smyth 2000; Cox and Ireland 2006). Contractors tend to seek structural solutions to marketing issues, resulting in contractors offering undifferentiated services organized by procurement route and building types (Smyth 2006). However, this does not mean relationship marketing cannot be applied to construction. Indeed, it has been argued that firms can chose to invest and allocate resources to relationship marketing and management (cf. Barney 2003), recognizing that this exposes firms to higher risks in the short-to-medium term (Smyth, 2000). Additionally, client drivers have required changes in working practices amongst contractors to the extent that RC has been adopted for projects and client programmes; however, there is piecemeal evidence of contractors going beyond a top down approach of RC applied on a project-by-project basis, towards a more behavioural approach (e.g. Smyth 2000; Kumaraswamy and Rahman 2006; cf. Smyth and Edkins 2007).

In order to implement RM into construction, contractors need to adopt a corporate strategy, managing their projects as a programme (Pellegrinelli 1997; Maylor *et al.* 2006). A separate model is needed for RM at the project level (Figure 4), which places greater investment emphasis upon the corporate-project interface and managing project transaction costs and supply chains. However, the project level requires integration into the corporate structure through investment and support systems particularly to inject quality, commitment, developing alternative solutions and support for managing critical events, whilst yielding converting project relationship value and revenues into corporate revenues and profit (Pryke and Smyth 2006).

The KAM function plays a significant role at the corporate-project interface in construction, taking responsibility for all projects for a client, concurrent and sequential, and thus is responsible for chunks of the contractor's total programme. This bridges the corporate level and project level. If a KAM has responsibility for a series of clients, this may constitute a segment of the contractor's market. Such accounts and segments may cut across procurement routes and building types, thus challenging the traditional corporate solutions to marketing as primarily structural ones (cf. Smyth 2006).

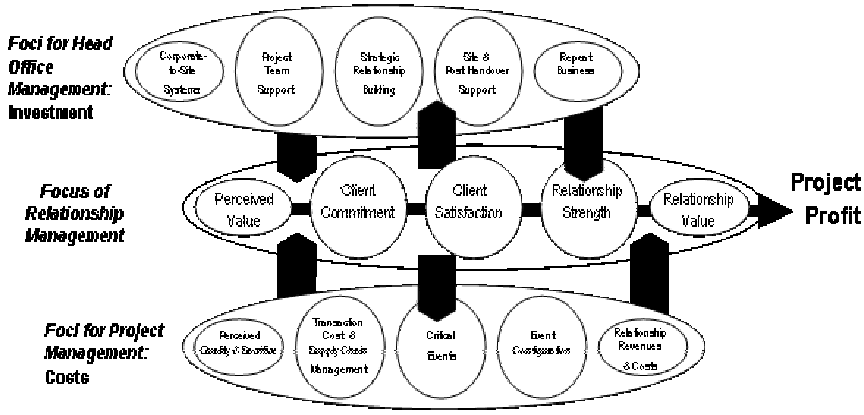


Figure 4: A simplified model of relationship project management (Source: Pryke and Smyth 2006)

A KAM can be a senior sales person (business development director), a contracts manager or a board director, depending upon strategy and client importance (cf. Kempeners and van der Hart 1999). It is the responsibility of KAMs to increase client satisfaction, thus increase the chances for repeat business as well as increasing market reputation by adding value through relationships (Pryke and Smyth 2006). Therefore, actions to add value to the services on the one hand, and problem solving to address critical events or moments of truth on the other hand are amongst the most important for the KAM function. A vital and neglected part of delivering client satisfaction in construction has been identified as consistency of service within projects and continuity of service across projects for clients (Smyth 2000; cf. Wilkinson 2006). Consistency refers here to the service character and quality received on a project and continuity that the character, hence quality is maintained across projects so that the experience received by a client on one project is the same or similar on others.

Two models have been identified at the project level for consistency (Smyth 2000; Pryke and Smyth 2006):

- Relay team.
- Account handler.

The relay team model is most suited to construction for transaction cost management. Resources are allocated to projects to maximize efficiency from the contractor view point, which may include changes in key personnel at each stage of the project from tendering presentations to completion on site, each change constituting a leg of the relay. However, this does not necessarily maximize effective service delivery. Ideally, the baton represents consistency and continuity whereby expectations of the client, promises made to the client, technical and process project information is handed on at the changeovers with some overlap (cf. Winch 2000). In practice, many contractors figuratively make changeovers that either “drop the baton” or personnel do not “carry one”. The result is that client requirements and hence satisfaction suffers. The relay team works where the baton is passed and client are aware of the changes in personnel in advance and the reasons for the changes (Smyth 2000).

The account handler model has a single person of contact for the client and is ultimately in charge (overseer) throughout the project. This is similar to, and might be performed by the KAM, but the role can be project specific, reflecting the project rather than programme as the management focus within many contractors, in other words, the 'account' and project are synonymous. Applying RM, the account and the client programme (segment of the contactor's total programme of projects) are synonymous, the KAM managing at this level. An RM strategy decision is whether to have a layered approach, whereby the KAM operates at the programme level, with account handlers or relay teams at project level, decisions depending upon factors such as project complexity, transaction cost management and linkages to other strategic and functional areas, such as procurement and estimating. Heads of all key functions – responsible board director, KAMs, estimating, account handler, supply chain managers, contracts director and project manager as roles which are not necessarily mutually exclusive – will constitute the decision-making for any particular project on the contractor side, together with complementary roles among the client and their design team (Smyth 2000).

The level of investment in systems and support from the corporate centre of the firm under RM is more than the requirement to satisfy continuous improvement of project partnering and strategic partnering (client programme and segment of the contractor programme), supply chain management and other approaches that come under RC. To make RM work aggregated behaviour (norms or organizational culture) and behavioural codes of conduct (prescribed procedures) need to be in place that go further than reaction to new formal and informal contracting agreements under RC. KAMs have an important role in modelling and guiding the implementation of appropriate behaviour for their projects and clients. It has been found that contractors still have to address the behavioural issue, tending to leave appropriate behaviour to the responsibility of individuals rather than proactive management by the firm (Smyth and Edkins 2007) – they have been practically influenced by transaction cost management and arguably adopted limited horizons through transaction cost theory in the form of RC rhetoric and fashion (cf. Green 2006).

The concepts and application of different approaches to relationship development and management in projects has been a major stimulus in the identification of a *relationship paradigm* for the MoPs (Pryke and Smyth 2006; Smyth and Morris 2007). This section has explored how RM and KAM can conceptually be applied in construction, clarifying the distinction of this approach from other approaches, in particular RC. However, conceptual possibility becomes relevant to practice upon application.

METHODOLOGY AND METHODS

Two paradigms are being applied: marketing-based RM, and a relationship approach within the management of projects (Pryke and Smyth 2006). Management by definition concerns causal powers for generating particular outcomes or events. Management has socially constructed prescriptive agendas. The prescription is needed because outcomes are contingent upon fertile conditions in the overall operating context (social, political and environmental), the social conditions for the object (social, technical and socio-technical in the case of construction projects). Therefore a methodology is required that is not merely instrumental in identifying general patterns, but can offer explanation between the socially constructed theory for both general and specific events (Smyth *et al*. 2007). Critical realist methodology satisfies these criteria, recognizing the context specificity, which renders events or outcomes dependent upon contingent conditions (Sayer 1992; Smyth and Morris 2007 in construction). Following Danermark *et al*. (2002), this research covers the first two stages of a six-stage research process six stage research process, the literature review emphasizing extensive research, intensive research being needed to substantiate conceptual possibilities following implementation. An action research method is being used to help through combining participation and observation (see Dunnette 1976). It is typically associated with the interpretative methodology within ethnography, and is sometimes associated with empiricist approaches. It is suited for this study because it engages at a fine grain of analysis, so that both the general and particular are identifiable. The case study deals with the initial stages of KAM implementation and later consideration will be necessary to assess whether customer satisfaction and benefits are realized.

CASE STUDY

KAM is a conceptual possibility, yet only takes on complete relevance once seen in the field. Yet there have been attempts to apply KAM. These have been short lived because partial implementation will not work in the long run, hence the need for RM, and because the commitment must be embedded into firms as a core competency (Pralahad and Hamel 1990). However, several large contractors are beginning to consider and adopt RM.

Some empirical context is needed in which to locate the detailed case study. One medium-to-large sized UK firm appointed a board level marketing director as KAM, who spent two days every week looking after the interests of its key client portfolio (a supermarket chain), liaising internally with those responsible for projects and externally with clients to ensure actions were aligned to expectation, to add value that arose through a series of innovations in working practices that directly benefited the client. In this case, RM was embodied in an individual, rather than being embedded and owned by the firm, consequently the function was lost when the individual ceased to work for the firm (Smyth 2000).

A second case involved a niche market leader in partnership housing in the UK, the KAM function again being led by the marketing director. This firm experienced considerable success embedding RM into the firm short-term, the approach not being robust enough to withstand on the one hand becoming complacent about some basic tenets of the execution of project management, and on the other hand withstanding structural change imposed by the parent company on the niche market contractor.

A third case involved a major internationally owned contractor appreciating the benefits of the KAM function, appointing project managers into the role for key UK clients, yet failing to appreciate how KAM fitted into RM. The consequence was a failure to resource the KAM role, thus the KAMs took their focus off the client and were fighting for internal resources to achieve their set objectives.

The action research case of the detailed case study centres upon a large the national business of an international UK contractor. One of the management studied RM within a part-time interdisciplinary masters programme around MoPs. He influenced both board and senior management of his employer to explore application. A consultancy and training involvement for the firm developed on RM, and a monitoring process set up, initially to cover a one-year implementation period.

The organizational structure was traditional, following typical hierarchical lines of communication and accountability. The Customer Directors acted as the sales force, serving a business organized on a project-by-project basis with co-ordination occurring at the level of the Operations Directors. Clients were categorized into green, amber and red according to priority, which was predominantly based upon (potential) profit margins, yet the criteria were not always clear to the Customer Directors.

The new strategy was to introduce RM with the Customer Directors (CDs) acting as KAMs with the aim to increase customer satisfaction, improve repeat business, especially through cross-selling and raise net margins to 3–4%, except where certain clients were identified as giving rise to other explicit strategic benefits, such as covering a base-load of overheads, being efficient payers to increase return on capital employed, and provided sector track record and reputation to use to secure other clients. The implementation phase is reported here, the extent of benefits to customer will become apparent at a later stage.

A new structure has developed, in two phases. The first phase involved giving the KAM function authority, placing CDs in a separate line of authority and developing cross-functional working. The second phase, having embedded the CD function was to create Sector Directors (SDs) to be responsible for clients whose business is transport and energy, rail, retailing, and facilities management for example (Figure 5). The result is less hierarchical and more organic, depicting the growing horizontal as well as vertical communication and accountability (cf. Millman 1996). This is a snapshot and the picture continues to evolve and become formalized.

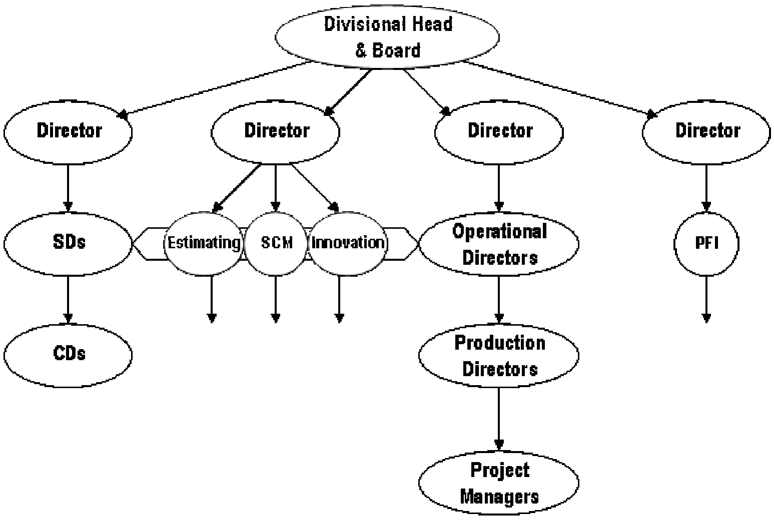


Figure 5: Simplified model of current organizational structure and KAM function

The KAM function therefore operates at two levels: SDs and CDs under a Board Director (cf. Kempeners and van der Hart 1999). Under the KAM function *Sector Plans* are being developed by SDs (cf. market segment planning), *Customer Account Plans* have been developed for individual clients (cf. sales planning), and *Relational Development Plans* within clients have been developed with a specific remit to build relationships and add service value (cf. relationship marketing sales tactics-cum-process plans, which contrasts with the former marketing mix-style *Tender Approval Form* as the project strategy at the tender stage). However, SDs and CDs require more than business development skills, requiring for example developed management skills (Millman 1996), and a detailed understanding and knowledge of technical, product and service issues (McDonald *et al*. 1997). The developed management skills include the ability to work across functional departments and roles. The SDs and CDs are charged with that role. Currently, there are two aspects. First, Sector meetings are chaired by the SDs and involve the Operational Directors, CDs are charged with responsibility for communication opportunities in the business development pipeline, updating *Relational Development Plans*, determining relationship ownership amongst the CDs, rating clients, plus actions to be taken. Rating clients uses the green, amber, red approach based upon (potential) net profit margins, but has yet to be developed into a more sophisticated model based upon relationship value over the client life cycle and margins derived from the added value component. Second, cross-functional working is also engaged with Estimating. This is seen as a vital role in determining profitable value added opportunities. This currently happens on a reasonably informal basis, which may evolve into a formal approach in time. Yet to develop is the cross-functional working with SCM and Innovation, which should prove to be significant for adding value, improving service and client satisfaction in the medium-term. All these aspects are vital components for achieving consistency within a project and continuity of service for a client programme.

Table 2: Summary of case study implementation

KAM Roles	KAM Functions	KAM Outcomes
Board Director	Develop roles	
	Create functional authority	Devise systems and support
	Manage KAM roles and functions	Raise net margins to 3–4%
Sector Directors (SDs)	Embed KAM function	Implement systems and support
	Sector Plan development	Increase customer satisfaction
		Improve repeat business
	Customer Account Plan management	Raise net margins to 3–4%
		Increase customer satisfaction
	Sector Meetings	Increase cross-selling
	Manage Commercial Directors	Increase customer satisfaction
Customer Directors (CDs)	Business Development (relationship marketing)	Improve repeat business
	Relational Development Plans	Increase customer satisfaction
	Cross-functional working	Increase customer satisfaction
	Manage RM-Client programme and project interfaces	Increase customer satisfaction
Operational Meetings	Attend Sector Meetings	Increase customer satisfaction
	Deliver added service value in programmes and projects	Increase customer satisfaction
		Raise net margins to 3–4%
		Improve repeat business

This represents a significant shift in emphasis from "just getting the job done" or task-orientation (Handy 1997) towards tailoring services to meet client expectations that are within the power of the contractor to deliver. In essence, reverses the 80:20 Pareto rule from suppliers having 80% focus on cost of production and delivery and to an 80% focus upon service quality, as it is this less or intangible service element that has been found to constitute 80% of customer satisfaction (e.g. Ford *et al*. 2003). Pratt (1999) identified the same 80:20 mismatch in construction, which in this contractor is beginning to address in a comprehensive way. This case reports upon the implementation of KAM to date; however, it is expected that the strategy will evolve and how clients respond remains to be seen, and the ways in which the are perceived to benefit has yet to come through the KAM system.

CONCLUSION

The paper has shown that relationship marketing and management are conceptually possible for adoption into contracting and has shown that it is being applied by way of a detailed case study using action research methods within a critical realist methodology. The paper has presented the initial findings concerning implementation, further study being required over a longer timescale to assess the tangible benefits of adopting relationship marketing and management. Both the concepts and application provide clarification to frequent confusion and misunderstanding concerning the scope and limits of RC and the potential for relationship marketing and management.

REFERENCES

Barney, J B (2003) *Gaining and Sustaining Competitive Advantage*. New Jersey: Prentice-Hall.

Berry, L L, Shostack, G L and Upah, G D (1983) *Emerging Perspectives on Service Marketing*. Chicago: American Marketing Association.

Christopher, M, Payne, A and Ballantyne, D (2001) *Relationship Marketing: creating stakeholder value*. Oxford: Butterworth-Heinemann.

Cox, A and Ireland, P (2006) Relationship management theories and tools in project procurement, *In:* S D Pryke and H J Smyth (Eds.) *Management of complex projects: a relationship approach*. Oxford: Blackwell.

Danermark, B, Ekström, M, Jakobsen, L and Karlsson, J C (2002) *Explaining Society: critical realism in the social sciences*. Abingdon: Routledge.

Dunnette, M D (Ed.) (1976) *Handbook of Industrial and Organizational Psychology*. Chicago: Rand & McNally College Publishing.

Ford, D, Gadde, L-E, Håkansson, H and Snehota, I (2003) *Managing Business Relationships*. Chichester: Wiley.

Green, S D (2006) Discourse and fashion in supply chain management, *In:* S D Pryke and H J Smyth (Eds.) *Management of complex projects: a relationship approach*. Oxford: Blackwell.

Grönroos, C (2000) *Service Management and Marketing*. London: John Wiley and Sons.

Gruneberg, S L and Ive, G (2000) *The Economics of the Modern Construction Firm*. Basingstoke: MacMillan.

Gummesson, E (2001) *Total Relationship Marketing*. Oxford: Butterworth-Heinemann.

Handy, C B (1997) *Understanding Organizations*. London: Penguin.

Kempeners, M and van der Hart, H W (1999) Designing account management organizations. *Journal of Business and Industrial Marketing*, **14**(4), 310–27.

Kotler, P, Armstrong, G, Saunders, J and Wong, V (1996) *Principles of Marketing*. Hemel Hempstead: Prentice Hall.

Kumaraswamy, M and Rahman, M (2006) Applying teamworking models to projects, *In:* S D Pryke and H J Smyth (Eds.) *Management of complex projects: a relationship approach*. Oxford: Blackwell.

Maylor, H, Brady, T, Cooke-Davies, T, and Hodgson, D (2006) From projectification to programmification. *International Journal of Project Management*, **24**(8), 663–74.

McDonald, M, Millman, T and Rogers, B (1997) Key account management: theory, practice and challenges, *Journal of Marketing Management*, **13**, 737–57.

Millman, T (1996) Global key account management and systems selling. *International Business Review*, **5**(6), 631–45.

Ojasalo, U (2001) Key account management at company and individual levels in business-to-business relationships. *Journal of Business and Industrial Marketing*, **16**(3), 199–216.

Pellegrinelli, S (1997) Programme management: organizing project-based change. *International Journal of Project Management*, **15**(3), 141–9.

Prahalad, C and Hamel, G (1990) The core competencies of the organization. *Harvard Business Review*, **63**(3), 79–91.

Pratt, J (1999) Understanding clients – the Egan imperative, *In:* H J Smyth (Ed.) *Proceedings of the 4th National Construction Marketing Conference*, July, Centre for Construction Marketing in association with CIMCIG, Oxford Brookes University, Oxford.

Pryke, S D and Smyth, H J (2006) *The Management of Complex Projects: a relationship Approach*. Oxford: Blackwell.

Reichheld, F F (1996) *The Loyalty Effect*. Boston: Harvard Business School Press.

Sayer, R A (1992) *Method in Social Science: a realist approach*. London: Routledge.

Smyth, H J (2000) *Marketing and Selling Construction Services*. Oxford: Blackwell.

Smyth, H J (2006) Competition. *In:* D Lowe and R Leiringer (Eds.) *Commercial Management of Projects: defining the discipline*. Oxford: Blackwell.

Smyth, H J and Edkins, A (2007) Relationship Management in the Management of PFI/PPP Projects in the UK. *International Journal of Project Management*, **25**(3), 232–40.

Smyth, H J and Morris, P W G (2007) An epistemological evaluation of research into projects and their management: methodological issues. *International Journal of Project Management*, **25**(4), 423–36.

Smyth, H J, Morris, P W G and Kelsey, J M (2007) Critical Realism and the Management of Projects: epistemology for understanding value creation in the face of uncertainty, paper presented at *EURAM 2007*, 16–19 May, INSEAD, Paris.

Spencer, R (1999) Key accounts: effectively managing strategic complexity. *Journal of Business and Industrial Marketing*, **14**(4), 291–309.

Storbacka, K, Strandvik, T and Grönroos, C (1994) Managing customer relationships for profit: the dynamics of relationship quality. *International Journal of Service Industry Management*, **5**(5), 21–38.

Wilkinson, S (2006) Client Handling Models for Continuity of Service. *In:* S D Pryke and H J Smyth (Eds.) *Management of complex projects: a relationship approach*. Oxford: Blackwell.

MANAGING HUMAN RESOURCES WITHOUT HUMAN RESOURCES MANAGEMENT DEPARTMENTS: SOME EXPLORATORY FINDINGS ON A CONSTRUCTION PROJECT

Paul W. Chan[1]

School of the Built Environment, Northumbria University, Ellison Building, Ellison Place, Newcastle upon Tyne, NE1 8ST, UK

There has been a growing interest in human resources management (HRM) in construction. The dominant discourse has, however, concentrated on criticising the industry's lacklustre approach towards HRM, with writers promoting the use of more formal methods of managing human resources in construction. Yet, little has been done to fully explain how informal HRM practices can work in construction. This study arose from an opportunity to investigate this within a medium-sized contractor, which did not have a HR department. Through a series of 19 interviews and documentary evidence collected, the recruitment, employee deployment and development practices of the case study organisation are examined, providing evidence that informal HRM can be effective.

Keywords: case study, deployment, development human resources management practices, recruitment.

INTRODUCTION

There has been growing interest in human resources management (HRM) in construction over the last decade. Textbooks have been introduced on this subject, including Langford *et al.* (1995), Druker and White (1996) and more recently, Loosemore *et al.* (2003). Following the Latham (1994) and Egan (1998) agenda, the UK construction industry has also seen the promotion of the Respect for People (RfP) initiative (Movement for Innovation (M^4I), 2000). This greater emphasis placed on human resources and human relations in construction indicates a movement beyond the dominance of the technical rationalism found in much work associated with construction management research, especially in relation to the literature on construction planning.

However, whilst there is a surge in the number of academic publications on the subject, the uptake of HRM practices in industry still lags behind (see Dainty *et al.*, 2000). Writers have suggested that the transience of the industry and the widespread use of casualised self-employed labour (Winch, 1998) results in the lack of formal employment of HRM in construction (see Debrah and Ofori, 1997). In fact, Haas *et al.* (2001) found that formalised HRM systems tend to be under-utilised in a sector that devolves HRM practices to line managers (Renwick, 2003) based on the project site.

[1] paul.chan@unn.ac.uk

The construction industry is made up largely of small and medium-sized enterprises (SMEs), which often do not have HRM departments. Indeed, Dainty *et al.* (2000) have suggested that construction companies tend to rely on less formal structures in terms of managing the employment relationship. More recently, Raidén and Dainty (2006) indicated that construction organisations tend to display the traits of a “chaordic” (a balance between the chaotic and the orderly) organisation. Chan and Kaka (2007) also observed that benign paternalistic relationship between site managers and their workers tend to underpin the employment relationship in the construction project environment.

Although the dominant discourse suggests that construction organisations are not very good in engaging with strategic HRM (SHRM) (Raidén and Dainty, 2006), the extant literature remains relatively opaque in terms of explaining how informal HRM actually work in construction. A research opportunity arose to help plug this gap. Access was granted to a medium-sized construction company without a HRM department for the purpose of understanding the informal mechanisms of how human resources are managed. This paper presents and discusses some preliminary but illuminating findings. The next section will outline the salient points raised in the many debates surrounding HRM in construction.

HRM DEBATES IN CONSTRUCTION

The consideration of human resources in construction in the academic literature has only emerged relatively recently. In the existing body of knowledge, there has been much criticism over the industry’s lacklustre approach towards HRM. Dainty *et al.* (2000) suggest that construction companies tend not to place HRM as top priority. Chan and Kaka (2007) also observed that construction managers often put technical planning ahead of workforce issues. This reinforces Green’s (1999) arguments against the industry’s adoption of lean principles. Green (1999) suggested that managers often do not consider the impacts of lean tools and techniques on workers’ autonomy and job satisfaction.

Druker *et al.* (1996) also suggested that the emphasis on construction planning meant that human resources are often treated as another factor of production and implied that construction organisations rarely operationalise the rhetoric of soft HRM (i.e. welfare for workers). Many writers have looked at skills development, for instance, to support the assertion that HRM features less prevalently in construction (see Beckingsdale and Dulaimi, 1997; Forde and MacKenzie, 2004; and Clarke, 2006). Indeed, Dainty *et al.* (2000) promoted the need for sophisticated ways of managing human resources by calling on companies to consider human resources more strategically. Chan and Cooper (2006) indicated that this could be done by reflecting on recruitment, employee deployment and development practices within construction organisations.

Nonetheless, Raidén and Dainty (2006) questioned this dominant discourse by claiming that their case study organisation did consider the development of their human resources, albeit not formally. They explained that due to the transient nature of construction work, construction organisations often had to balance the long-term planning of human resources against short-term economic efficiencies necessary to deliver projects. Raidén and Dainty (2006) suggested that further studies be undertaken to support their claim. As mentioned previously, an opportunity arose that enabled the examination of HRM within a medium-sized contracting firm. Interestingly, this firm did not have a HR department. Therefore, the study sought to:

- Explore the practice of HRM within this firm and examine how the practice of HRM filters down to the project level, and to;
- Investigate the recruitment, deployment and development practices within the firm.

THE STUDY

The study focussed on ConstructCo, a construction company specialising in concrete operations that co-existed with three other subsidiary companies under a parent group, ConstructPLC (see Figure 1 below). Of the companies, ConstructCo was the biggest in size (based on persons employed, turnover and portfolio of activities). Moreover, in terms of employment, ConstructCo had a mix of both directly employed general labourers and subcontract labour (including self-employed, labour-only subcontractors and trade subcontractors). Thus, it was decided that ConstructCo would be most appropriate in providing insights into the dynamics of HRM in construction. At the time of study, ConstructCo undertook a project involving the structural phase of the redevelopment of a large retail unit in the Northwest of England. With no office based in the region – ConstructPLC was based in Hertfordshire – there was an expansion opportunity of creating a regional office near the project. Due to confidentiality reasons, the names of the companies have been anonymised here.

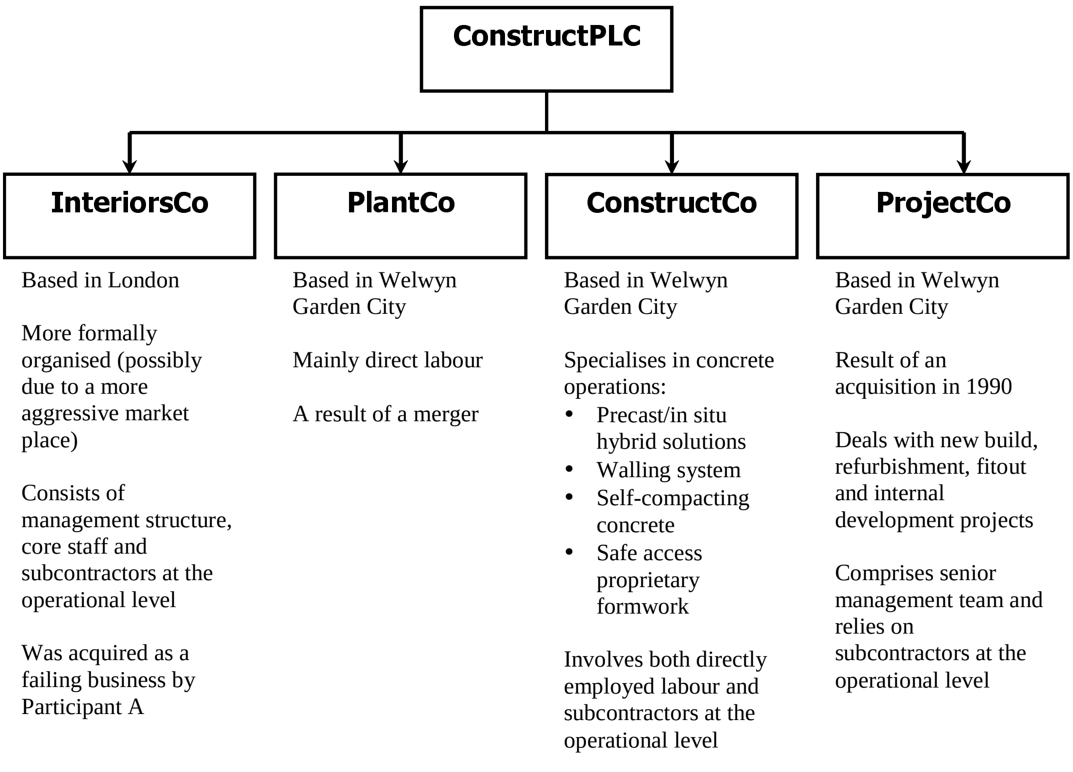


Figure 1: Organisational structure showing the location of ConstructCo

A total of 19 semi-structured interviews were conducted with key participants in ConstructPLC from November 2004 to April 2005. Each semi-structured interview lasted between 1 to 3 hours and was audio-taped for analytic reference. The interview followed an interpretive research framework intended to gather rich descriptions of the recruitment, deployment and development practices that went on in ConstructCo, as well as what went well in the project, what went badly in the project, and what were the perceived improvements in retrospect. To ensure a full understanding of both strategic and operational considerations of HRM, a range of interviewees were selected to cover both managerial staff and workers on site (see Table 1 below for a profile of the interviewees). A summary sheet was completed immediately after each interview. This captured key points made by interviewees whilst the interview remained fresh in the researcher's mind. The summary sheets were then sent back to the interviewees to ensure accuracy of the researchers' understanding of the issues raised (see Figure 2 below).

Table 1: Profile of interviewees.

Interviewee	Organisation / Position	Job Function
A	ConstructPLC – Chairperson	Senior Management
B	Construct PLC – Group Secretary	Senior Management
C	ProjectCo – Managing Director	Management Team
D	PlantCo – Managing Director	Management Team
E	ConstructCo – Chief Estimator	Management Team
F	ConstructCo – Project Manager	Line Manager
G and H	ConstructCo – Joiners	Employee
J and K	ConstructCo – General Operatives	Employee
L and M	ConstructCo – Steelfixers	Employee
N	ConstructCo – Construction Manager	Line Manager
P	ConstructCo – General Foreman	Line Manager
Q	Main contractor of project	External
R	ConstructCo – Site Engineer (Agency Worker)	Employee
S	ConstructionCo – Regional Director	Management Team
T	InteriorCo – Managing Director	Management Team
U	Employment agency – Consultant (responsible for placing Participant R on the project	External

<table>
<tr><td colspan="2">Interviewee:
Telephone:
Place:</td><td>Interview date:
Today's date:
Written by:</td></tr>
<tr><td colspan="3">1. What were the main issues or themes that struck you in this interview?</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">2. Summarise the information you got (or failed to get) on each of the target questions for this interview</td></tr>
<tr><td>Question</td><td>Information</td><td>Emergent theme?</td></tr>
<tr><td>Interviewee background</td><td></td><td></td></tr>
<tr><td>General HR Policy</td><td></td><td></td></tr>
<tr><td>HR Recruitment System/Process</td><td></td><td></td></tr>
<tr><td>HR Allocation System/Process</td><td></td><td></td></tr>
<tr><td>HR Development System/Process</td><td></td><td></td></tr>
<tr><td>Key Issues</td><td></td><td></td></tr>
<tr><td colspan="3">3. Anything else that struck you as salient, interesting, illuminating or important in this interview?</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">4. What new (or remaining) target questions do you have in considering future interviews?</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">5. Any general concerns?</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Figure 2: A blank interview summary sheet.

EMERGENT FINDINGS

This section discusses the emergent findings, which are presented as follows. First, a general overview of HRM in ConstructPLC is explained. An analysis of recruitment, deployment and development practices at the project level (specific to ConstructCo and the large retail project) will then follow.

HRM in ConstructPLC

HRM across ConstructPLC, with the exception of PlantCo, was generally informal. There was no designated department within any of the four companies in ConstructionPLC with the main remit of managing human resources. It was observed that HRM was construed by managerial staff as bearing the same administrative functions of personnel management in the 1980s, i.e. the management of payroll, pensions, sick leave and holiday entitlement. The function of accounting, therefore, played an important role in HRM in ConstructPLC.

Nonetheless, people were seen to be important assets throughout ConstructPLC’s business and the managerial staff all operated an “open-door” policy for all their members of staff. Typical issues include career progression (usually through formal wage reviews and/or the less prominent informal appraisal process) and disputes on e.g. non-performance on health and safety on site. A number of interesting observations were made here.

First, there was a clear distinction between office-based staff and site-based operatives. Although the “open-door” policy applied to everyone within ConstructPLC, it was found that senior managers in ConstructPLC were mainly responsible for office-based staff, devolving the responsibility of managing site-based operatives to site managers. This distinction pervaded throughout recruitment, deployment and development practices, explained below.

Second, it was indicated by the interviewees that the informality of HRM meant that “open-door” policy could work quickly and effectively. That is, problems could be solved at an instant, usually “through a phone call”. There was, however, no concerted effort in tracking down how this “open-door” policy manifested in reality, i.e. it was purely on a case-by-case basis. Still, there was a suggestion made by a number of interviewees that the “open-door” policy was seldom utilised. Within the confines of this study, however, it was unclear whether this was due to a lack of emerging problems, or whether staff and operatives were fairly autonomous and so maintained their discretion not to consult managers, or simply because staff and operatives were not aware of the existence of an “open-door” policy due to dominance of informal HRM. It is likely to be a dynamic interaction between the three reasons put forward here.

Following on from the distinction between office-based staff and site-based operatives, it was noted that despite the informality of HRM in ConstructPLC, there existed a natural hierarchy in the redress of issues. So, operatives naturally consulted their foremen, and if the problem remained unsolvable, then the problem would be referred to the project manager, and then the next higher up (e.g. regional director) and so forth. Similarly, a discontented secretary would first approach her/his line manager, and if the problem persisted, the line manager would refer to the next higher up and so forth.

However, the "open-door" policy also meant that staff and operatives could potentially pass over their line managers and go directly to the next higher up. Again, this was not usually the case as the interviewees believed that the problems tend to be solved fairly quickly and effectively by line managers. Furthermore, interviewees believed there was a culture of respect across the group and that everyone operated in sync within the informal framework. It was discovered that this culture resulted from a somewhat top-down approach, which could be traced back to the Chairman of ConstructPLC (Participant A). In fact, new managers are constantly initiated into the group/company as Participant B claimed that "if a manager does not share this value of respecting the workers, then he will be called in and I will say this is how it is done in [ConstructPLC]". Indeed, ConstructPLC operated like a family business, even though Participant A started out as an employee of the group. Still, he bore the main responsibility for building up the group through business acquisitions, which probably explained the deep entrenchment of his philosophy throughout the four companies in ConstructPLC.

As mentioned previously, PlantCo maintained a more formal framework of HRM. The Managing Director of PlantCo (Participant D) kept a Microsoft Excel spreadsheet of all the employees in the company, detailing their individual pay rates, holidays and more importantly, training needs and deployment. In other words, according to Participant D, he would know where (i.e. which project in which geographic location) a particular employee is located at any given time, and at what point in time should an employee undergo a particular training regime. PlantCo stood out from the rest chiefly because all the employees (mainly plant operators and maintenance staff) were directly employed by the company. Therefore, it made business sense to enforce a more formal framework of managing human resources. However, this was considered to be an exception rather than a rule for the construction industry, since the plant hire sector of the industry tended to employ directly due to the need for staff reliability in operating plant (which are expensive capital investment).

Indeed, the wider macro-level labour market dictated the extent to which HRM was formalised in ConstructPLC, and the construction industry at large. Because of the dependence on sub-contract labour and the encouragement of self-employment (Winch, 1998), it is extremely difficult to shift to direct employment even though companies like ConstructPLC are willing to do so. As a result, HRM remains informal where sub-contract labour and self-employment perpetuates (see Drucker and White, 1996). Moving towards more formal frameworks in sectors where direct employment appeared to be the norm e.g. in plant hire. Let us now turn to the HRM practices in ConstructCo.

Recruitment practices in ConstructCo

The distinction between office-based staff and site-based operatives was extremely pronounced in recruitment practices of ConstructCo. For office-based staff, recruitment was fairly stagnant since the workforce remained relatively stable (there was a major reshuffle/rethink of office-based job roles in the early 1990s by the Group Secretary). Instead, recruitment of office-based staff was performed mainly internally, usually through promotion/developmental opportunities for applicants. Examples were given of helpdesk staff progressing to become a quantity surveyor, or receptionists upgrading to become an administrator. Where external recruitment was concerned, an example was found in the appointment of the regional director (Participant S) of ConstructCo.

In this case, a need to recruit was identified in ConstructCo's intention to expand its presence in the Northwest of England. A recruitment agent was approached and a suitable applicant was selected based on matching up the job and person specifications with the CVs of potential applicants. Further interviews (either face-to-face or over the telephone) with suitable applicants to validate work experience and establish the individual's vision for ConstructCo in the Northwest were conducted by the recruitment agent where appropriate (based on recruitment agent's discretion). According to the Group Secretary, appointment of office-based staff tended to be subjected to a probationary period. This allowed ConstructCo to "test" the employee to see if the representation of CV/interview is accurate. This practice emanated from a negative past experience where an employee's behaviour apparently transformed (for the worse) from the time of interview to the commencement of work.

Where site-based operatives were concerned, the process was less formal. Recruitment was normally done through the grapevine. The need to recruit was usually based on the effective start-date on-site. Calls would be made through known contacts, performed in the main by the general foremen. Such known contacts tended to exist in the foremen's heads (or notepads) and are amassed from the foremen's experience on previous projects. On the other hand, potential employment was elicited in the operatives' social setting, e.g. local builders' pub. Again, news of projects starting up would be spread through the grapevine, either through the foremen's contacts or the operatives' initiative to approach ConstructCo. The recruitment process usually began with the question "are you looking for work?" or "are you looking for workers?"; followed usually by a discussion of pay and start date. Working conditions were rarely raised as these were notionally associated with the reputation of the firm.

In the selection process, greater prominence was placed on the worker's attitudes (Is she/he reliable? Will she/he turn up for work? Will she/he get along well with other workers?); and less emphasis on technical abilities. There was a general belief by the interviewees that technical abilities would be evidenced by (a) references offered by the prospective worker, usually based on previous projects worked on; and/or (b) technical questions asked during the interview, although this is performed in a rather *ad hoc* manner. Furthermore, the flexibility of the workforce through sub-contract labour and self-employment meant that there was an ease of firing incompetent operatives if an operative was found to be a fraud. Again, where new operatives were employed, a probationary period of a week (or sometimes a day) would be in place so that ConstructCo retained the flexibility to fire the "frauds". Indeed, it was observed that the probationary period represented a somewhat experimental, if informal, approach in which ConstructCo managed the recruitment of staff (both office-based and site-based).

In both office-based staff and site-based workers, a disconnection between theory and practice of recruitment was found. Ideally, according to Taylor (2002), a good recruitment and selection process should begin with rigorous and robust job analysis that should give rise to detailed job and person specifications. However, it was found that in reality, this was rarely performed. Instead, there was a reliance on traditionally-defined roles (e.g. a traditional joiner, bricklayer, secretary, receptionist) with a greater emphasis placed on quantitative measures (i.e. how many bodies do we need?) as compared with the quality of skills involved.

Because of the informal framework of ConstructPLC the selection process was also less formalised. Furthermore, this was usually founded on the subjective evaluation of the interviewer (using the interviewer's personal judgement of what is good or bad, which often reflects benchmarking against the interviewer's perception of their own performance). Moreover, safeguards, e.g. probationary period, were put in place to ensure the attainment of the right fit in the recruitment of human resources. Such experimentation suggested that there was some kind of thinking process behind ConstructCo's recruitment, albeit in an informal manner.

Deployment practices in ConstructCo

Deployment was found to be less essential and virtually non-existent at the project level because of the reliance on sub-contract and self-employed labour. The allocation of resources was usually tied up with the recruitment and selection process, often arising rapidly upon the award of a contract. Similar to recruitment practices above, it was believed that traditionally-defined job roles were crucial since this enabled the project manager and general foreman to establish the numbers needed. However, this meant that there was lesser focus on the quality of skills tied to a specific job role. This did pose problems at the project level with the need to re-hire as a result of incompetence, e.g. errors due to site engineers and fraudulent joiners.

Furthermore, deployment of human resources appeared to be a dynamic combination of the planned and emergent. For instance, it was found that there was an inclination towards resource planning where sub-contract labour (particularly in terms of work packages) was concerned. Conversely, where directly-employed labour was involved, deployment tended to be a matter of matching availability with the dynamic needs derived from the project schedule.

Interestingly, it was discovered that general operatives tended to be directly employed whereas more highly skilled labour e.g. joiners and steelfixers tended to be sub-contract and/or self-employed labour. This supports the argument that flexibility is the prevailing criteria for HRM at the project level. In other words, the use of general operatives acted as a buffer for variations in project schedule and workloads that could occur throughout the life of a project; whereas the use of highly skilled labour was task-specific and therefore could be planned according to a given programme.

A limitation of this study needs to be stated. Whilst the discussion on deployment related mainly to site-based operatives, deployment was not mentioned in the discussion of office-based staff.

Development practices in ConstructCo

As mentioned previously, ConstructPLC as a group operated on an informal basis. There was therefore no predetermined career progression path within the group for each of the four companies. Developmental opportunities were largely contingent on the individual employee's discretion and initiative. However, this begged a worrying question as to whether individual employees were best placed to identify and act on their developmental needs. Furthermore, there was the aspect of commercial viability of developing employees. Often, it was difficult to balance employees' developmental needs with the operational pressures of delivering projects (see Beckingsdale and Dulaimi, 1997; Dainty *et al.*, 2000).

It was found that when interviewees were asked what they were good at in terms of their personal skills and experience, all the participants invariably found it difficult to articulate these in a coherent manner. Two possible reasons account for this. First, participants might have found it difficult to frame an answer to such a question because they were not used to describing their abilities. Second, the hesitation could simply be the result of (lack of) personal reflection rather than uncertainty. Even so, all the participants chose to focus on such softer skills as communication and inter-personal skills when discussing their strengths, whilst downplaying their technical abilities. Furthermore, on the question of possible improvements, it was noted that a majority of the interviewees did not actually talk about improving their skills base. Instead, most interviewees chose to highlight external influences, e.g. improving information flow, reducing the rigidity of the personal protection equipment policy by the main contractor; with only a handful of interviewees (mainly managerial) who talked about specific personal skills e.g. motivating people, enhancing lateral thinking.

There was recognition of a dearth of training in the industry. Unsurprisingly, therefore, training for the improvement of technical abilities or even softer skills was not performed in a structured manner and would appear to be on a case basis. Nonetheless, training existed in health and safety where there is mandatory legislation. Furthermore, there was a general perception that informal mentoring and learning-by-watching/doing took place with younger operatives learning from more experienced operatives (within and more likely beyond ConstructCo e.g. operatives from other firms on previous/current projects). However, this learning was not structured and again dependent on personal initiative and aptitude to learn.

Where office-based staff was concerned, there was some evidence of investment in training. However, this appeared to be *ad hoc* and on a case-by-case basis. An example was provided of the helpdesk staff progressing to become a quantity surveyor, through a sponsored degree course (both financial sponsorship and in terms of study time).

CONCLUSIONS

In conclusion, the study revealed that whilst there was no formalised HR department in ConstructPLC, there was consideration of HRM through the examination of recruitment, deployment and development practices of the case study via a delicate balance of the planned and emergent. This corroborates, to a certain extent, with Raidén's and Dainty's (2006) notion of the 'chaordic' organisation. The case findings highlighted a greater tendency for formalisation of HRM procedures for office-based staff and direct employees, with more informalisation for project-based staff. The extant literature criticises such informality, however, such informality has served ConstructPLC well. This is because of the somewhat patriarchial, top-down approach driven by the Chairman (Participant A).

Specifically, recruitment was performed tactically based on the award of a contract. Job analysis was rarely performed; instead, there is reliance on traditionally-defined job roles, placing more emphasis on skills planning from a quantitative perspective. Negative impacts of incompetent employees (i.e. inappropriate skills) were mitigated and flexibility encouraged through probationary periods administered informally during the recruitment of office-based and site-based staff. This, however, could potentially increase the cost (and wastage) of re-hiring, and arguably the potential problem of latent skills shortages (Chan and Cooper, 2006). Deployment of skills was virtually non-existent as recruitment was often used as a means to resource a project. Development opportunities were available to directly-employed labour, although this was contingent on the capacity and capability of the individual labourer. Development opportunities were, however, non-existent for non directly-employed labour, with the exception of mandatory training requirements of health and safety.

REFERENCES

Beckingsdale, T and Dulaimi, M F (1997) The investors in people standard in UK construction organisations. *CIOB Construction Papers*, 9–13.

Chan, P and Cooper, R (2006) Talent management in construction project organisations: do you know where your experts are? *Construction Information Quarterly*, **8**(1), 12–18.

Chan, P and Kaka, A (2007) The impacts of workforce integration on productivity. *In*: A R J Dainty, S Green and B Bagilhole (Eds.) *People and culture in construction: a reader*. London: Spon Press.

Clarke, L (2006) Valuing labour. *Building Research and Information*, **34**(3), 246–256.

Dainty, A R J, Bagilhole, B M and Neale, R H (2000) The compatibility of construction companies' human resource development policies with employee career expectations. *Engineering, Construction and Architectural Management*, **7**(2), 169–178.

Debrah, Y A and Ofori, G (1997) Flexibility, labour subcontracting and HRM in the construction industry in Singapore: can the system be refined? *International Journal of Human Resource Management*, **8**(5), 690–709.

Druker, J and White, G (1996) *Managing people in construction*. London: Institute of Personnel and Development.

Druker, J, White, G, Hegewisch, A and Mayne, L (1996) Between hard and soft HRM: HRM in the construction industry. *Construction Management and Economics*, **14**, 405–416.

Egan, J (1998) *Rethinking construction*. Report from the construction task force. UK: DETR.

Forde, C and MacKenzie, R (2004) Cementing skills: training and labour use in UK construction. *HRM Journal*, **14**(3), 74–88.

Green, S (1999) The missing arguments of lean construction. *Construction Management and Economics*, **17**, pp. 133–137.

Haas, C T, Rodriguez, A M, Glover, R and Goodrum, P M (2001) Implementing a multiskilled workforce. *Construction Management and Economics*, **19**, 633–641.

Langford, D, Hancock, M R, Fellows, R and Gale, A W (1995) *Human resource management in construction*. Harlow: Addison Wesley.

Latham, M (1994) *Constructing the team*. London: HMSO.

Loosemore, M, Dainty, A and Lingard, H (2003) *Human resource management in construction projects: strategic and operational approaches*. London: Spon Press.

Movement for Innovation (M^4I) (2000) *A commitment to people 'our biggest asset'*. Respect for People (RfP) working group report, Rethinking Construction.

Raidén, A B and Dainty, A R J (2006) Human resource development in construction organisations: an example of a "chaordic" learning organisation? *The Learning Organisation*, **13**(1), 63–79.

Renwick, D (2003) Line manager involvement in HRM: an inside view. *Employee Relations*, **25**(3), 262–280.

Taylor, S (2002) *People resourcing*. 2ed. London: CIPD.

Winch, G. (1998) The growth of self employment in British construction. *Construction Management and Economics*, **16**(5), 531–542.

EXCHANGE RELATIONSHIPS IN BUILDING SERVICES MAINTENANCE ACTIVITY: A TEST OF TRANSACTION COST ECONOMICS AND THE RESOURCE DEPENDENCY VIEW

Adrian J Bridge[1]

School of Urban Development, Queensland University of Technology, 2 George Street, Brisbane, Queensland, Australia

The firm is faced with a decision concerning the nature of intra-organizational exchange relationships with internal human resources and the nature of inter-organizational exchange relationships with market firms. In both situations, the firm can develop an exchange that ranges from a discrete exchange to a relational exchange. Transaction Cost Economics (TCE) and the Resource Dependency View (RDV) represent alternative efficiency-based and power-based explanations of the nature of the exchange relationship. The aim of the paper is to test these two theories in respect of air conditioning maintenance in retail centres. Multiple sources of information are generated from case studies of Australian retail centres to test these theories in respect of internalized operations management (concerning strategic aspects of air conditioning maintenance) and externalized planned routine air conditioning maintenance. The analysis of the data centres on pattern matching. It is concluded that the data supports TCE – on the basis of a development in TCE's contractual schema. Further research is suggested towards taking a pluralistic stance and developing a combined efficiency and power hypothesis – upon which Williamson has speculated. For practice, the conclusions also offer a timely cautionary note concerning the adoption of one approach in all exchange relationships.

Keywords: human resource management, maintenance, relational contracting, transaction cost economics.

INTRODUCTION

The firm is faced with a decision concerning the nature of intra-organizational exchange relationships with internal human resources and the nature of inter-organizational exchange relationships with market firms. In both situations, the firm can develop an exchange that ranges from a discrete exchange to a relational exchange. Transaction Cost Economics (TCE) and the Resource Dependency View (RDV) represent alternative efficiency-based and power-based explanations of the nature of the exchange relationship. With regard to more mainstream construction activity, progress has been towards empirical testing of TCE on the issue of inter-organizational relationships, including Eccles (1981). Again, in terms of mainstream construction, Cox and his colleagues have focused on developing a power-based approach to inter-organizational relationships (for example, Cox 1999; Cox and Townsend 1998; Lamming and Cox 1999). With respect to building services maintenance, Lai *et al*. (2006: 333) considered the application of TCE on the issue of

[1]a.bridge@qut.edu.au

inter-organizational relationships. However, this empirical contribution does not focus on the specific operationalization of the TCE dimensions. Therefore, despite all of this progress, there remains substantial scope to further develop and test more widely established approaches to operationalizing the TCE and RDV dimensions on the issue of inter-organizational exchange relationship in building maintenance. There also appears to be an absence of work that tests these theories with respect to intra-organizational exchange relationships in building services maintenance. The aim of the paper is to test these two theories in respect of one particular sector of building services maintenance activity – namely, air conditioning maintenance in retail centres. More specifically, the investigation focuses on intra-organizational relationships with Operations Managers (OMs) and inter-organizational relationships with mechanical services contractors (MSCs).

In the next section, TCE and RDV are briefly described in terms of their application, hypotheses and relationship. Details concerning the research design and results then follow. Finally, the conclusions focus on the relative power of TCE and RDV and the prospects for a pluralistic approach.

THEORETICAL PERSPECTIVES ON EXCHANGE

Transaction cost economics

Williamson proposes that a range of exchange relations (from discrete to relational exchange) may be economical in inter-organizational exchange, whilst the richest form of relational exchange is substantially the purview of vertical integration. Hence, Williamson's initial working hypothesis can be refined thus:

- The greater the potential for the appropriation of quasi-rents, or *hold-up*, the more likely the activity will be internalized *with an ensuing relational exchange*.
- The lesser the potential for hold-up, the more likely that the activity will be externalized *with a lesser relational exchange than that associated with internalization.*

Williamson's (1999) constructive critiques concede the possibility that internalization may be selected as the first choice organizational form (in pursuance of improvements in production costs) and not as the last resort. If internalization is chosen for purposes other than to avoid hold-up, then relational exchange may not always occur. Indeed, it seems reasonable to expect as wide a range of exchange relationships within the firm as we find between firms. This would then lead to the possibility of relaxing an implied heuristic within TCE's contractual schema. That is, the requirement that TCE should account simultaneously for the make-or-buy decision *and* the nature of the exchange relationship with respect to internalization. In other words, and with respect to internalization, there are appears to be the opportunity to explore separating these two decisions and treating them as *two – sequential* decisions. By treating the make-or-buy decision and the nature of the exchange relationship as two sequential decisions, and having selected internalization, the focus of the transaction switches from the *activity* (on the issue of the make-or-buy decision) to the *resource* (on the issue of the nature of the exchange relationship decision). In turn, this may effect the operation of all of the TCE variables assumptions – as explained by Bridge (2004). In this study, however, the semi-structured interviews revealed that the conventional approach remained the most effective way to measure each of the TCE dimensions.

That said, one of the significant matters that arises out of this development in TCE's contractual schema is the prospect of some significant level of hold-up without necessarily a high level of uncertainty and frequency. The employment contract is different from other contractual arrangements, in so far as the exact nature of the tasks is deliberately undefined. The employer purchases a capacity to work, such that if the employer can organize to extract a higher level of productivity from the employee then no cheating has occurred (Marginson 1993). In this sense, the influence of exogenous uncertainty is much reduced by virtue of the nature of the adaptability built into the employment contract. Having made non-trivial investments in a human resource, the firm has an interest in this resource delivering a better than perfunctory performance and maintaining their employment with the firm. This may then lead to a *weaker form* of potential hold-up than that conventionally described in TCE. Whilst this weaker form of hold-up may be insufficient to explain the firm's decision to internalize the activity associated with the human resource, it may be sufficient to explain the nature of the exchange relationship with the human resource.

Resource dependency view

Pfeffer and Salancik (1978) develop the notion of power and dependency in their version of RDV and envisage a number of different ways by which a firm may choose to respond to demands made on it from a discernable group that may be internal or external to the firm. In circumstances in which the firm is dealing with an important exchange and is not able to develop substitutes nor diversify, and is unable to undertake a relevant merger or vertically integrate, then the firm is faced with the remaining strategy of attempting to adapt by mediating the exchange through some kind of formal and/or informal social coordinating mechanism – amounting to relational exchange. Pfeffer and Salancik's (1978) hypothesis can be refined thus:

- The greater the degree of bilateral dependence (two-way interdependence and balanced both ways), the greater the likelihood that *the exchange is relational and based on credible commitments (as positive balancing measures*).
- The greater the degree of unilateral dependence (one-way interdependence and unbalanced), the greater the likelihood that *the exchange is discrete with high prices or credible threats as negative balancing measures* (in addition to the tacit threat of using some other exchange partner or use of simple termination clauses).
- The greater the degree of independence (two-way and balanced), the greater the likelihood that *the exchange is discrete with reasonable/low prices and an absence of credible threats* (reliance on tacit threat of using some other exchange partner or simple termination clauses only).

Relationship between TCE and RDV

RDV covers many of the same issues as TCE, in so far as both these approaches incorporate a major concern for the negative effects of opportunism and hold-up in complex situations that cannot be controlled easily by the contract alone (Rindfleisch and Heide 1997: 31). However, TCE treats asset specificity as a situation of resource dependency that independent and voluntary agents deliberately take recourse to, whilst the power approach typically assumes such a situation to be unanticipated and unwanted by the dependent party (Groenewegen and Vromen 1996: 376). This situation is illustrated in Figure 1 and concerns the case of *special purpose investments*.

TCE and RDV both endeavour to explain the existence of relational exchange (as shown in the mid-point of Figure 1) by appealing to the influence of dependency. However, in the case of *special purpose investments*, the point of departure between TCE and RDV concerns the nature of motivation surrounding the relational mid-point in Figure 1. On the one hand, TCE sees the parties to the exchange actively seeking this position in the interests of efficiency, with the dominant party willing to share some of its power. On the other hand, RDV considers that the parties have reached this position reluctantly – for the time being, neither party is able to attain more power in the relationship, so that almost a stalemate develops.

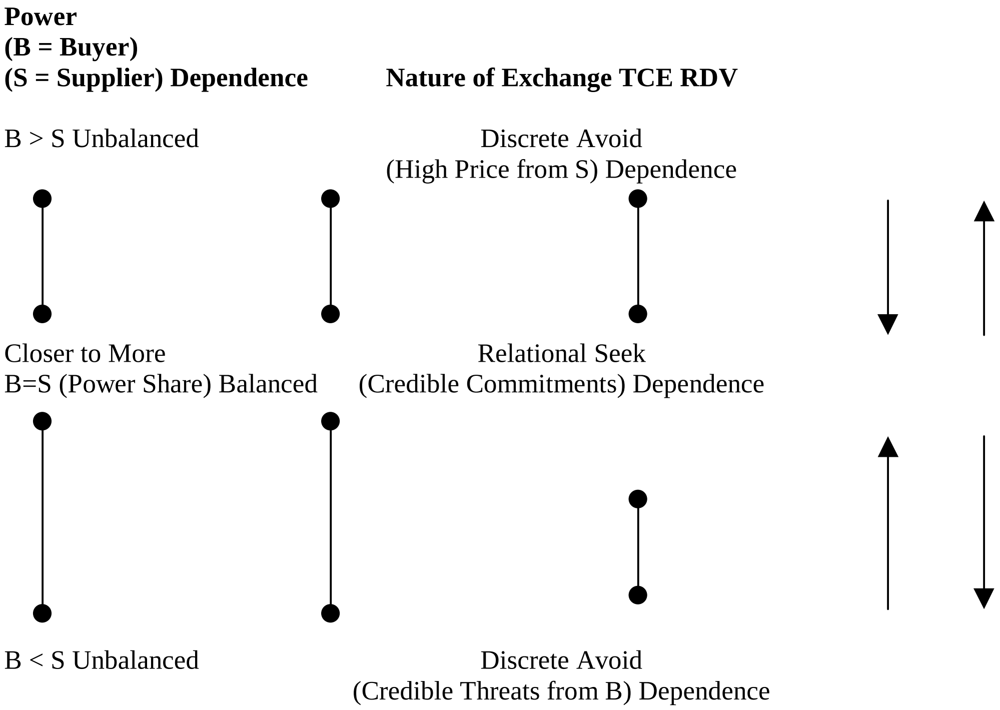


Figure 1: Special purpose investments – seeking dependency in pursuance of efficiency vs. avoiding dependency in pursuance of power

Without a move to the mid-point, inefficient outcomes may materialize. At one end of the scale, when the buyer is more powerful, then this could lead to higher prices (as the supplier prices the risk of the buyer appropriating profits). In contrast, when the supplier is more powerful, this could lead to credible threats (as the buyer may attempt to pre-empt the supplier’s *ex post* bargaining advantage). For TCE, any of these inefficient outcomes are a significant concern. Hence, this theory see actors attempting to mitigate and/or avoid these outcomes by *seeking dependencies* and dependency balancing, which includes developing harmonious relations as a preferred course of action. In contrast, RDV is much less concerned with these outcomes, choosing instead to view these developments as short-term inefficiencies, which are much less important than the longer-term survival of the firm. The survival characteristic that RDV emphasizes is *size*: larger firms are considered to be more resilient than smaller firms in the face of environmental changes.

The fundamental differences in the objectives of the firm in TCE and RDV, as illustrated in Figure 1, can be traced to different assumptions concerning rationality. TCE adopts a semi-strong form of rationality, or bounded rationality, as one of its behavioural assumptions, so that decision makers seek to optimize, within the bounds of their knowledge, the match between the governance structure and attributes of the transaction, in order to minimize transaction costs. Here, the firm is seen as focusing on each transaction in isolation and developing governance structures that deal with *ex post* and temporal dependencies. Thus, the operationalization in TCE centres around the individual transaction. In contrast, the firm in RDV is able to take a more holistic stance, and a less than optimal individual transaction might be an important part of a longer-term strategy to ensure the firm's survival. More specifically, the firm may be facing *ex ante* and ongoing dependencies that require a process of concession and/or avoidance and/or adaptation in order to restore the balance of power in favour of the focal firm. Thus, the operationalization in RDV goes beyond the characteristics of the individual transaction and focuses more on the *entire* exchange and possible multiple transactions between the parties. In summary, the strength of TCE relative to RDV turns largely on the market/competitive conditions surrounding the firm that determine the extent to which maximizing on transactions becomes an economic imperative.

RESEARCH DESIGN AND RESULTS

Explanatory case studies

The design and presentation of the explanatory case studies in this paper draws heavily from Yin (1994). An explanatory case study approach was adopted as means to test the hypotheses for two main reasons. First, the collection of data in respect of the research questions in this paper are not straightforward given the secrecy surrounding this kind of decision making. Here, interviews and other sources of evidence may be used to address some reluctance to provide detailed and open answers. Second, and consistent with the first reason, multiple sources of information are more effectively generated when a respondent has clearly in his/her mind a particular case (in this study, the case is taken to be a retail centre). Four criteria can be used to improve the quality of case studies: external validity; construct validity; internal validity; and reliability. The first three criteria are now used as a structure to present the case study design and results. Reliability refers mainly to issues associated with inconsistency arising out of data collection by multiple researchers. In this study, all data was collected by the author.

External validity

In pursuance of notion of *analytical generalization,* comprising *theoretical and literal replication,* six case studies of retail centres were selected. All of these are in one state's capital city in Australia. The cases shown in Table 1 were chosen to represent theoretical replication – in order to produce contrasting results but for predictable reasons (due to differences in the size of the centres). Whereas, the cases shown in Table 2 were selected on the basis of literal replication – with the expectation that they should provide similar results as for each of the first three cases.

In Table 1, the type and size of each retail centre is classified using the main classifications of retail centre developed by Property Council Australia (2000). Case Study 3 is partially air conditioned in contrast to full air conditioning in Case Study 3A. However, the nature of the air conditioning is these cases are similar – each with an absence of central plant and a Building Management System. Moreover, the extent or scale of air conditioning is comparable, in terms of maintenance time and the value of the contract. Thus, these two cases are expected to provide similar results. Table 1 adopts an economic distinction between internalization and externalization (Lai 2000). Consistent with this approach, wholly owned subsidiaries are described as firms that are internal to some other larger firm. The implication of an internalization or externalization is the creation of intra-organizational relationships and inter-organizational relationships respectively. As mentioned in the introduction, this paper focuses on intra-organizational relationships with OMs and inter-organizational relationships with MSCs. Finally, although there are a few general maintenance staff in Case Studies 1, 1A, 2 and 2A, the OMs indicated that these staff are not able to be used to replace the MSCs even for a very short period of time. Therefore, general maintenance is a distinctly different activity to planned routine mechanical maintenance, does not affect the inter-organizational relationships in this paper and is beyond the scope of this paper.

Table 1: Brief profile of case studies used to show theoretical replication

Retail Centre	**Case Study 1 Super and Major Regional (> 50,000m^2)**	**Case Study 2 Regional (30–50,000m^2)**	**Case Study 3 Sub-Regional and Neighbourhood (< 30,000m^2)**
Type and size	Major Regional	Regional	Sub-Regional
Mechanical Services	Fully Air Conditioned	Fully Air Conditioned	Part Air Conditioned
Centre Management	By Centre Management firm external to Owner	By Centre Management firm internal to Owner	By 1 x Part-Time Centre Manager internal to Owner
Operations Management	By 1 x Full-Time Operations Manager internal to Centre Management firm	By 1 x Full-Time Operations Manager internal to Owner/Centre Management firm)	By 1 x Part-Time Operations Manager internal to Owner
Planned Routine Mechanical Maintenance	By Mechanical Services Contractor (with internal technical staff) external to Centre Management firm	Mechanical Services Contractor (with internal technical staff) external to Owner/Centre Management firm	Mechanical Services Contractor (with internal technical staff) external to Owner

Table 2: Brief profile of case studies used to show literal replication

Retail Centre	Case Study 1A Super and Major Regional (> 50,000m^2)	Case Study 2A Regional (30-50,000m^2)	Case Study 3A Sub-Regional and Neighbourhood (< 30,000m^2)
Type and Size	Super Regional	Regional	Neighbourhood
Mechanical Services	Fully Air Conditioned	Fully Air Conditioned	Fully Air Conditioned
Centre Management	By Centre Management firm internal to Owner	By Centre Management firm internal to Owner	By Centre Management firm external to Owner
Operations Management	By 1 x Full-Time Operations Manager internal to Owner/Centre Management firm	By 1 x Full-Time Operations Manager internal to Owner/Centre Management firm	By 1 x Part-Time Operations Manager internal to Centre Management firm
Planned Routine Mechanical Maintenance	By Mechanical Services Contractor (with internal technical staff) external to Owner/Centre Management firm	Mechanical Services Contractor (with internal technical staff) external to Owner/Centre Management firm	Mechanical Services Contractor (with internal technical staff) external to Centre Management firm

Construct validity
Establishing theoretical propositions prior to the conduct of any data collection is an essential part of explanatory case studies. In particular, extant theory – along with associated empirical work, promote the operational measures of theoretical constructs and help avoid subjectivity in the collection of data. This study employs two tactics to increase construct validly – namely, the use of multiple sources of evidence (to create, through data triangulation, converging lines of inquiry) and the procedure of allowing the informants (decision makers) the opportunity to review and comment on the case study report. The decision maker with respect to the intra-organizational relationship with the OM is the Centre Manager (CM) and the decision maker with regard to the inter-organizational relationship with the MSC is the OM.

The multiple sources of evidence comprised a structured questionnaire completed by each decision maker, an interview with each decision maker and documentation provided by the decision maker and collected by the author in relation to the decision maker's firm and the retail centre. With regard to the structured questionnaire, Table 3 gives a very brief outline of the questions used. Apart from each question being contextualized for each decision maker, in terms of the relationship that this manager is responsible for, the same questionnaire was administered to each decision maker and received by the author in advance of the interview with the decision maker. As a starting point for the design of the questionnaire, previous and well-established empirical studies were used as the basis of the development of the items used to capture the dimensions on the nature of the exchange relationship and the two theories (as mentioned in the comments column in Table 3). In order to translate these previous studies from the context of the originating activity to the activity and relationships under investigation in this paper, semi-structured interviews were then undertaken with a CM and an OM in Brisbane and a final draft of the questionnaire was then piloted with six CMs and eight OMs across Sydney, Melbourne, Adelaide and Perth. As a clearer example of the results of this translation procedure, reproduced below are the full questions – in respect of the Items 1 and 2 concerning Human Asset Specificity (HAS) in the version of the questionnaire contextualized for OMs – that determine the relationship with the MSCs:

- Item 1: How long would it take a recently appointed and competent contractor to become familiar with your centre and to reach their expected level of performance? Please insert months:___Months
- Item 2: How much did your current contractor in your centre need to customize their technology (hardware and software), knowledge, skills, policies, procedures and practices to suit your centre? Please circle on the scale: Minimal adaptations 1 2 3 4 5 6 7 Substantial adaptations

In contrast to the questionnaire, the other questions in the case study interviews were largely unstructured/open-ended. The extent of documents provided by each decision maker comprised mainly company information, internal letters, maintenance schedules, induction handbooks and documents downloaded from websites relating to the specific retail centre and also representing the firms concerned. Finally, and on the conclusion of the final case study interview, decision makers were sent a case study report (with written receipt confirmation obtained) confirming their answers to the questionnaire (including any adjustments the decision maker made to their initial answers during the course of the interview), along with confirmation of any other relevant advise provided by the decision maker.

Internal validity

Internal validity is an important concern for explanatory case studies and when the analytic tactic of pattern matching is advocated – as is the approach in this paper. The application of pattern matching inevitably leads to some interpretation in the analysis of results as part of creating summary empirical patterns of data and then in matching these patterns with theoretically predicted patterns. However, the subjectivity involved in this process is minimized in this study by developing guidelines to translate the quantitative data generated by the questionnaire into summary empirical patterns and then reviewing other sources to establish whether this information corroborates or contradicts the summary empirical patterns.

Table 3: Items in structured questionnaire

Outline of item	Comments
Nature of exchange relationship: Dimensions: *Solidarity* • Item 1: Cooperation • Item 2: Expectation of continuation *Role Integrity* • Item 1: Complexity of all relations • Item 2: Complexity of expectations *Mutuality* • Item 1: Lack of monitoring of performance • Item 2: Imprecise terms and conditions of contract	Each item in each of the three dimensions of this dependent variable is based on Kaufmann and Stern (1988). Kaufmann and Stern's approach is preferred by the author as this approach considers the nature of the exchange to be a continuum from discrete exchange to relational exchange. A 7-point semantic differential response format is used for each item – with the 7/high end labelled in terms of a high incidence of the item and 1/low end of the scale labelled in opposite terms - a low incidence of the item.
TCE: Dimensions: *Human Asset Specificity (HAS)* • Item 1: Time to reach expected performance • Item 2: Specific adaptations required *Uncertainty (Exogenous and Endogenous)* • Item 1: Difficult to predict range of tasks • Item 2: Difficult to predict time to complete each task • Item 3: Difficult to predict frequency of each task • Item 4: Difficult to specify performance requirements • Item 5: Likelihood of changes in core knowledge and skills • Item 6: Difficult to monitor performance • Item 7: Unfairness of objective measures of performance *Frequency* • Item 1: Full-time equivalent staff (FTE)	The three TCE dimensions are attributable to Williamson (1985). As part of the semi-structured interviews used in the development of the questionnaire, HAS was advised by interviewees as the most relevant/dominant type of asset specificity. Items 1 and 2 are based on John and Weitz (1988). The uncertainty items are based on Walker and Weber (1989) and Anderson and Schmittlein (1984). The frequency item is also based on John and Weitz (1988). A 7-point semantic differential response format is used for the items – except for: • HAS Item 1: Measured in full-time equivalent months or days • Frequency Item 1: Measured in discrete numbers Again, with the 7-point semantic differential response format, the 7/high end labelled in terms of a high incidence of the item and 1/low end of the scale labelled in opposite terms - a low incidence of the item.
RDV: Dimensions: *Criticality* • Item 1: Lack of tolerance in correcting unsatisfactory performance • Item 2: Lack of tolerance in correcting unsatisfactory pay/working conditions *Magnitude of Exchange* • Item 1: Proportion of cost • Item 2: Proportion of revenue *Lack of Discretion* • Item 1: Lack of influence on actions • Item 2: Lack of influence on actions *Few Alternatives* • Item 1: Few other sources • Item 2: Few other sources	The items in each of Pfeffer and Salancik's (1978) four RDV dimensions are based on Provan *et al.*'s (1980) and Saidel (1991). A 7-point semantic differential response format is used for each item – with the 7/high end labelled in terms of a high incidence of the item and 1/low end of the scale labelled in opposite terms - a low incidence of the item. Since the exchange relationship is determined by the manager in the firm buying the service and based on this manager's perception of the net dependence in the exchange, both Item 1 and Item 2 are provided by this manger. The semi-structured interviews and the pilot study used in the development of the questionnaire ensured that both Item 1 and Item 2 are able to be readily answered by the buyer.

This data and the summary empirical patterns are shown in Table 4 (see overleaf), along with the guidelines (key to Table 4). The approach used to review other sources of evidence centred on the identification of text and quotations that could be directly connected with the theoretical dimensions (for example, Bresnan 1991). That said, the focus in this paper is on the presentation and analysis of the questionnaire data.

Having summarized the empirical patterns using the guidelines in Table 4, the next step was to select a predicted pattern that corresponds with each of the empirical exchanges. In doing so, each of the inter-organizational relationships are considered efficient, on the basis that all the OMs felt they were paying a reasonable/low price for the service and there was a complete absence of any costly credible threats. This is significant in selecting the RDV predicted patterns, as different patterns would be selected for an inefficient discrete exchange in contrast to an efficient discrete exchange. In order to assess the match between empirical and predicted patterns, Yin (1994) advocates simple “eyeballing” of data to establish substantial matches and mismatches.

With regard to RDV and the net dependency column in Table 4 (overall mean), there is one match between the summary empirical pattern and the predicted pattern on the inter-organizational relationship between the centre management firm (represented by its OM) and the MSC in Case Study 1A. Moreover, if some tolerance is allowed and added to the Table 4 guidelines that specify a balanced dependence when the mean scores are exactly equal, then the empirical patterns concerning the other external relationships could be interpreted as showing some reasonably strong match with predicted patterns. However, the low mean scores representing both the buyer and supplier in terms of the internal relationships create a substantial mismatch between the empirical and predicted patterns. In contrast, TCE’s asset specificity shows empirical patterns that substantially match the predicted patterns - across both internal and external relationships

CONCLUSIONS

As relational exchanges were observed in the absence of bilateral dependency, the results do not support the RDV hypotheses. In contrast, the results provide clear support for TCE. Furthermore, this support for TCE is enhanced by evidence of analytical generalization created by the results. That is, differences are evident – as expected, between cases 1, 2 and 3 and between cases 1A, 2A and 3A in terms of TCE’s asset specificity. Here, larger centres require more time in which to process unique knowledge and information pertaining to the centre and its air conditioning system. At the same time, similarities between each case study and its companion “A” case study are also evident. More specifically, the results support Williamson’s assertion that asset specificity is the “big locomotive” in TCE. This support for TCE is based on the development in TCE’s contractual schema – that separates the make-or-buy decision and the nature of the exchange relationship decision, and then treats these two decisions as *two sequential* decisions. This development sees the resource (and not the activity) as the focus of the transaction when internalization has been selected and gives rise to the prospect of a weaker form of hold-up that can occur in the absence of a high level of uncertainty and frequency. This weaker form of hold-up is unlikely to help explain the make-or-buy decision but the results indicate that it has the potential to enhance TCE’s explanatory power on the issue of the nature of the exchange relationship.

Table 4: Case studies – results from questionnaire and summary empirical patterns of dimensions versus predicted patterns of dimensions

Exchange & Case & Summary	HAS TCE	Unc' TCE	Freq' TCE	Crit' RDV	Mag' of Exchan' RDV	Lack of Discr' RDV	Few Alt' RDV	Overall Mean B & S RDV	Exchange Empirical
CM-OM1 Summary:	6 mths, 5	1,2,2,2,3, 3,2	1	1,4	1,7	2,6	2,3	1.50,5.00	6,5,5,7,2,5
Empirical	High	Low	High					S>B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
CM-OM1A Summary:	6 mths 2	1,2,3,2,2, 4,1	1	2,1	3,7	6,6	5,2	4.00,4.00	6,7,5,2,2,6
Empirical	Mod'	Low	High					S=B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
CM-OM2 Summary:	3 mths, 5	1,2,2,2,3, 3,3	1	1,4	1,7	2,3	2,2	1.50,4.00	7,4,7,4,2,6
Empirical	High	Low	High					S>B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
CM-OM2A Summary:	3 mths, 5	2,2,2,2,2, 3,3	1	2,3	2,7	2,3	2,2	2.00,3.75	7,7,3,5,4,6
Empirical	High	Low	High					S>B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
CM-OM3 Summary:	2 mths 5	1,1,2,2,2, 2,2	0.5	2,4	2,7	1,3	2,3	1.75,4.25	6,4,5,7,3,7
Empirical	High	Low	Low					S>B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
CM-OM3A Summary:	3 mths 4	2,2,2,3,3, 3,3	0.33	5,4	3,7	2,4	5,2	3.75,4.25	7,6,4,4,2,7
Empirical	High	Low	Low					S>B Low	Internal
Predicted	High	Hi'-Low	Hi'-Low					S=B High	Relational
OM-MSC1 Summary:	23 dys, 3	1,2,3,1,3, 1,1	0.8	1,4	5,3	1,3	2,1	2.25,2.75	5,4,3,3,3,1
Empirical	Low	Low	Low					S>B Low	External
Predicted	Low	Hi'-Low	Hi'-Low					S=B Low	Discrete
OM-MSC1A Summary:	3 mths 5	2,2,2,2,4, 4,3	1	3,4	5,4	3,3	2,2	3.25, 3.25	6,3,6,3,3,3
Empirical	High	Low	High					S=B Low	External
Predicted	Mod'	Hi'-Low	Hi'-Low					S=B Low	Neutral
OM-MSC2 Summary:	5 days, 3	1,2,2,2, 3,2,1	0.03	1,4	6,3	1,3	2,1	2.5,2.75	6,5,4,1,1,1
Empirical	Low	Low	Low					S>B Low	External
Predicted	Low	Hi'-Low	Hi'-Low					S=B Low	Discrete
OM-MSC2A Summary:	8 days, 2	3,2,3,1,3, 2,3	0.4	2,3	4,4	1,3	3,2	2.50,3.00	5,3,3,3,2,2
Empirical	Low	Low	Low					S>B Low	External
Predicted	Low	Hi'-Low	Hi'-Low					S=B Low	Discrete
OM-MSC3 Summary:	4 days 3	1,2,2,1,3, 2,3	0.11	1,4	3,3	2,5	2,4	2.00,4.00	6,5,4,4,1,1
Empirical	Low	Low	Low					S>B Low	External
Predicted	Low	Hi'-Low	Hi'-Low					S=B Low	Neut'/Dis'
OM-MSC3A Summary:	1 day 1	1,1,2,1,2, 2,1	0.03	2,4	6,3	4,4	3,5	3.75,4.00	5,2,2,2,1,1
Empirical	Low	Low	Low					S>B Low	External
Predicted	Low	Hi'-Low	Hi'-Low					S=B Low	V.Dis'

Key

- Results in each cell are entered in the same order as the items are outlined in Table 3
- 7-point scales: E. High = Extremely High with mean closest to 7; V. High = Very High with mean closest to 6; High = mean closest to 5 and Low = mean between 1 and 4
- Extremely Relational = mean closest to 7; Very Relational = mean closest to 6; Relational = mean closest to 5; Neutral = mean closest to 4: Discrete = mean closest to 3; Very Discrete (V.Dis) = mean closest to 2 and Extremely Discrete = mean closest to 1
- HAS: Extremely High = >12 months; Very High = >6 months; High = > 2 months and Low = < 2 months
- Frequency: Extremely High = > 20 FTE staff; Very high = > 10 FTE staff, High = 1 to 9 FTE staff; and Low: <1 FTE staff
- RDV: Net dependency = mean of scores representing Buyer's dependency and Supplier's dependency – both from Buyer's perspective: Where imbalance (B>S or B<S) then low = difference of 3 or less and high = difference of 4 or more: Where balance (B=S) then low = same scores of 4 or less and high = same scores of 5 or more

For the vast majority of retail centres, the market for centre management (that includes operations management) and the market mechanical services can be most closely assigned to either the stereotypical market structure depicted by monopolistic competition (comprising more than a small number of firms) or to perfect competition (with many firms). Hence, the level of price competition in both these markets is at least reasonably strong. Therefore, the results are consistent with the expectation that TCE should be more powerful in more competitive markets that encourage firms to maximize on transactions. Furthermore, the other sources of evidence collected in this study, showed the existence of very settled intra-organizational and inter-organizational relationships. Again, this evidence is consistent with maximizing behaviour and the results in this paper that show TCE outperforming RDV.

In terms of further research, it seems important to explore the anticipated relative strength of RDV in markets in which the transaction is much more complex (perhaps including reciprocal trade and the influence of third parties) and in which there exists only a few buyers and/or few suppliers. Although TCE and RDV can be considered as alternative theories under a particular set of competitive conditions, these explanations can also be considered as complementary when a full range of competitive conditions are viewed. This would illustrate why it is that Williamson (1985: 236–8) feels that the power-based approach may be able to make a contribution and notes that a combined efficiency-power hypothesis is not able to be rejected. This combined hypothesis, perhaps best represented by TCE and RDV, would require the coexistence of different scientific research programmes (SRP), as TCE and RDV could not be part of the same SRP – given their different assumptions concerning rationality. Thus, the complementarity between TCE and RDV requires that a wider view be taken than say the complementarity between TCE and Resource-Based Theory – which may possibly be developed within the same SRP (Bridge and Tisdell 2004).

In terms of practice, and with respect to intra-organizational exchange, the results concerning the exchange between centre management firms and OM staff indicate that whilst these firms may be much more powerful than their OMs, these firms can prosper by sharing some power to create a relational exchange with these staff. This may be of some reassurance to mainstream construction firms seeking to avoid a command and control approach amongst their employees. On the other hand, and in terms of inter-organizational exchange, the results concerning the exchange between the centre management firms (represented by the OMs) and the MSCs show that, even in the presence of a recurring transaction (all six of the OMs interviewed in the case studies confirmed that they would expect the incumbent MSC to succeed at contract renewal), discrete exchange can be an economic and viable approach. Therefore, industry reforms incorporating normative prescriptions for widespread relational contracting lack relevance with respect to exchanges with contractors in this study's supply chain.

ACKNOWLEDGEMENTS

Comments made by James Risdale and anonymous referees on earlier drafts of this paper are gratefully acknowledged.

REFERENCES

Anderson, E and Schmittlein, D (1984) Integration of the sales force: An empirical examination. *Rand Journal of Economics*, **15**(autumn), 385–95.

Bresnan, M J (1991) Construction contracting in theory and practice: A case study. *Construction Management and Economics*, **9**, 247–63.

Bridge, A J (2004) The make-or-buy decision in relation to mechanical building services maintenance: A test of an integrated framework of vertical integration. *In:* R. Ellis and M. Bell (Eds.), *COBRA 2004*, 7–8 September, Leeds, RICS and Leeds Metropolitan University.

Bridge, A J and Tisdell, C (2004) The determinants of the vertical boundaries of the construction firm. *Construction Management and Economics*, **22**, 807–25.

Cox, A (1999) Power, value and supply chain management. *Supply Chain Management: An International Journal*, **4**(4): 167–75.

Cox, A and Townsend, M (1998) *Strategic procurement in construction: Towards better practice in the management of construction supply chains*. London: Thomas Telford.

Eccles, R G (1981) The quasifirm in the construction industry. *Journal of Economic Behaviour and Organisation*, 2(4): 335–57.

Groenewegen, J and Vromen, J J (1996) A case for theoretical pluralism. *In:* J. Groenewegen (Ed.) *Transaction Cost Economics and Beyond*. Dordrecht: Kluwer Academic Publishers.

John, G and Weitz, B A (1988) Forward integration into Distribution: An Empirical test of transaction cost analysis. *Journal of Law, Economics and Organisation*, **4**(fall), 121–39.

Kaufmann, P J and Stern L W (1988) Relational exchange norms, perceptions of unfairness, and retained hostility in commercial litigation. *Journal of Conflict Resolution*, **32**(3), 534–52.

Lai, L W C (2000) The Coasian market-firm dichotomy and subcontracting in the construction industry. *Construction Management and Economics*, **18**, 355–62.

Lai, J H K, Yik, F W H and Jones, P (2006) Critical contractual issues of outsourced operation and maintenance service for commercial buildings. *International Journal of Service Industry Management*, **17**(4), 320–43.

Lamming, R and Cox, A (1999) *Strategic procurement management: Concepts and case*. Bath: Earlsgate Press.

Macneil, I R (1974) The many futures of contracts. *Southern California Law Review*, **47**, 691–816.

Marginson, P (1993) Power and efficiency in the firm: Understanding the employment relationship. *In:* C. Pitelis (Ed.) *Transaction Costs, Markets and Hierarchies*. Oxford: Basil Blackwell.

Pfeffer, J and Salancik, G R (1978) *The external control of organisations: A resource dependence perspective*. New York: Harper & Row.

Provan, K G, Beyer, J M and Kruytbosch, C (1980) Environmental linkages and power in resource-dependence relations between organisations. *Administrative Science Quarterly*, **25**, 200–25.

Property Council of Australia (2000) *Glossary of property terms*. Brisbane: Queensland Division.

Rindfleisch, A and Heide, J B (1997) Transaction costs analysis: Past, present, and future applications. *Journal of Marketing*, **61**(October), 30–54.

Saidel, J R (1991) Resource interdependence: The relationship between stat agencies and non-profit organisations. *Public Administration Review*, **51**(6): 543–53.

Walker, G and Weber, D (1984) A transaction cost approach in make-or-buy decisions. *Administrative Science Quarterly*, **29**(September), 373–91.

Williamson, O E (1985) *The Economic Institutions of Capitalism*. New York: The Free Press.

Williamson, O E (1999) Strategy research: Governance and competence perspectives. *Strategic Management Journal*, 6, 1087–108.

Yin, R K (1994) *Case Study Research: Design and Methods*. 2Ed. California: Sage Publications.

REWARDING COST ESTIMATION ACCURACY

Said Boukendour[1]

Department of Administrative Sciences, University of Quebec, PO Box 1250-Hull, Gatineau (QC), J8X3X7, Canada

Some estimate inaccuracies are inherently related to the lack of available information whereas others are related to lack of disciplined behaviour in cost estimation processes. Then the issue is how to induce the appropriate behaviour for improving cost estimating accuracy? An estimator who predicts the cost of a project with a specified range of accuracy is like an investor who expects that a stock price will remain within certain limits during a certain period of time. A butterfly spread strategy, which is used by the investor, can by analogy used as a conceptual and methodological framework for designing an incentive system that would encourage estimate accuracy.

Keywords: accountability, estimating, incentives, options, spread.

INTRODUCTION

Estimate accuracy is of vital importance for effective decision-making and cost control for both owners and contractors. For the owners, underestimating a project creates the risk of cost overruns, which for being resolved will need additional funding or reducing in scope. In contrast, overestimating creates the risk that the project will be deemed unprofitable and wrongly rejected. If it is funded, the over-allocated money will be spent to the detriment of other projects. For the contractors, underestimating bid proposals create the risk of winning contracts that will be transformed into high loss later. Conversely, overestimating bid proposals create the risk of losing opportunities. In all cases, inaccurate estimates translate into loss of money that could jeopardize the profitability and even the survival of a company

There are several sources of estimate inaccuracies. Some are inherently related to the lack of available information due to the project definition and unforeseeable events and conditions such as changes in scope and requirement, technical problems and economic conditions. Others are related to the lack of skilled staff and disciplined behaviour in cost estimation processes (Mackie and Preston 1998; Flyvbjerg *et al*. 2002; GAO 2004)

Many efforts were undertaken to improve methods and tools but, to our knowledge very few have been made, neither in practice nor in the literature, to induce disciplined estimating behaviour through incentives. This article attempts to fill this gap by proposing a rewarding model based on an options spread strategy.

THE BUTTERFLY SPREAD EXPLAINED

In order not to annoy the reader who is unfamiliar with the financial jargon, let us introduce imaginary characters whose names are Peter and Sarah. Peter was a cost

[1] said.boukendour@uqo.ca

estimator prior to his retirement. Impassioned by forecasting, he enjoys speculating on stocks in order to pay the holidays of his dreams. During a ceremony to which Peter was invited, he met Sarah, a young cost estimator who had been recruited a few months before his departure from the company. He spoke to her about his speculating activities especially about his favourite strategy: a butterfly spread.

Recall that a stock option is the right to buy (call) or to sell (put) a stock or any other underlying asset at a certain price (exercise price) for a limited period of time. The buyer of the option is the holder of the option who decides whether to exercise his or her right. The seller of the option (the writer) is obliged to abide by the buyer's decision.

At expiration, the intrinsic value of the option is equal to the difference between the spot price and the exercise price. If this difference is positive, the option is in-the-money. Otherwise, it is out-of-the money and expires worthless. However, before the expiration date, the option's price is always positive. Even if it is very small, while the option is still alive, it remains possible that the stock price will rise beyond the exercise price.

A butterfly strategy is a viable strategy for one who thinks that the stock will not experience much of a net rise or decline at the expiration date. Using only calls, the butterfly spread consists of selling two calls at the middle exercise price and buying two calls: one at the lowest exercise price and the other at the highest exercise price.

The first time that I used this strategy, explained Peter, was to bet on the stock of the company which was at £700. I was betting that the price would not fall below £600 and would not rise above £800 the three next months. I established a butterfly spread by selling two calls of £700 exercise price for £30 each, and buying one call of £600 for £60, and another of £800 for £10. All the options were European options and matured in three months time. Unlike American option, the European options can only be exercised at the expiration date. Finally, my net cash debit was only of £10.

At the expiration date, the stock was at £750. So, I exercised the call of £600 and gained £150 but the two calls of £700 which I sold were exercised against me and I lost £100. Obviously the option of £800 expired worthless since the spot price was of £750. Finally, my net gain was of £50, i.e.: 500%. If with a little more chance the stock remained stable at £700, I would have the maximum profit of £150, i.e.: 1500%.

Figure 1 below depicts the potential profits and losses of Peter according to the quality of his forecast. Note that the shape of the curve looks like a butterfly from which the strategy gets its name.

Figure 1: Payoffs

REWARDING COST ESTIMATION ACCURACY

Peter suddenly asked Sarah: “Why wouldn't you use the butterfly spread for rewarding the cost’s estimators as a function of the quality of their prediction?” Indeed, an estimator who predicts the cost of a project with a specified range of accuracy is like an investor who expect that a stock price will remain within certain limits during a certain period of time. Therefore, the cost estimator can bet on his or her estimate using a butterfly spread.

Sarah replied “Where would you obtain the options to establish the spread”. Do not worry, said Peter, it is not necessary that these options actually exist. Options are contracts, and the essence of a contract is commitment. The company and the cost estimator can establish the spread by an agreement just as many institutions do with options over the counter. Hence, they become reciprocally the buyers and the sellers of all the options involved in the spread. There is also no need for the market to exist since the calls can be priced using an options pricing model.

The long history of options pricing theory began in 1900 when the French mathematician Louis Bachelier used Brownian motion to model the stock prices. But, it is only in 1973 that Black and Scholes developed the first pricing formula for an European call options. They assume that stock prices adjust to prevent arbitrage, change continuously, and follow a log normal distribution. Further, they assumed that the interest rate and the volatility of the stock remain constant over the life of the option. These restrictions are necessary to derive their formula using Brownian motion and differential stochastic calculus:

$$
\begin{aligned}
&c = SN(d_1) - Ke^{-rT}N(d_2) \\
&with: \\
&d_1 = \frac{\ln(S/K) + (r + \frac{1}{2}\sigma^2)T}{\sigma\sqrt{T}} \\
&d_2 = d_1 - \sigma\sqrt{T}
\end{aligned}
$$

Where:

C: call price

S: current stock price

N(.): cumulative standard normal distribution

K: strike price

σ: instantaneous standard deviation

r: risk-free interest rate

T: time to expiration

Since the publication of this seminal article, numerous options pricing models that remove some of these restrictions have been proposed in the literature. Haug (1997) provides a complete guide of option pricing formulas accompanied by their code. Despite its unrealistic assumptions, the Black-Scholes model remains attractive in practice because it is simple and easy to use. For this reason, we shall use it to illustrate how to price the options involved in the spread.

Let us substitute S for the estimated cost, K for the strike (exercise) price, r for the risk-free interest rate, T for the project duration, and σ the project cost volatility. Except for the project cost volatility all the other parameters are given.

Volatility is a very important parameter of the option price, which is not directly observed but only approximated using statistical means. Let us assume that the ratio of actual cost to the estimated cost follows a log-normal distribution. This assumption is consistent with many empirical findings (Garvey 2000).

Thus, the cost volatility can be estimated on the basis of a sample of completed representative projects. The standard deviation can be calculated as the logarithm of the percentages of their under runs and overruns, i.e.: ln [(actual-estimate) /estimate].

$$\sigma = \sqrt{\sum_{i=1}^{n} \ln(\frac{A-E)}{E})^2}$$

Where A_i and E_i are respectively the actual cost and the estimated cost of the project i, i=1,2…n.

A STYLIZED EXAMPLE

Let us consider a project estimated at £6 million whose volatility is estimated at 29% as indicated previously on the basis of a sample of 67 completed projects. Table 1 below describes the potential profits and losses of the cost estimator depending on the level of confidence. If, for instance, the level of confidence is set at ±σ, the cost estimator will establish the butterfly spread by buying one call at £ 4,26 million exercise price for £1,824,911, selling two calls at £6 million exercise price for £691,735, and buying one call at 7.74 million exercise price for £205,263. The cost estimator will invest the net debit of £646,704. If the actual cost is exactly £6 million, the cost estimator will earn the maximum gain of £1.74 million.

Table 1: Payoffs as a function of confidence intervals

Confidence	Calls premiums for the lowest, middle and highest exercise price			Net debit	Maximum gain	Return
	Lowest	Middle	Highest			
±0σ	691735	691735	691735	0	0	
±0.25σ	906316	691735	519931	-42776	435000	1017%
±0.50σ	1167111	691735	385612	-169252	870000	514%
±0.75σ	1474497	691735	282721	-373747	1305000	349%
±σ	1824911	691735	205263	-646704	1740000	269%
±2σ	3480440	691735	53203	-2150172	3480000	162%
±3σ	5220000	691735	12969	-3849499	5220000	136%

When the actual cost deviates from the target of £6 million, the maximum profit drops until reaching the limit of net debit, which is the maximum loss of the estimator. Calculations also show that the net debit and the maximum profit drop when the accuracy increases. For instance, when the accuracy increases from one sigma to half a sigma, the net debit decreases from £646,704 to £169,252 (-74%) whereas the maximum profit decreases only from £1.74 million to £870,000 (-50%). Thus, the maximum profit drops less quickly than the net debit does. This explains the higher returns of the narrowest range of accuracy. In other words, the more accurate is the estimate, the higher the cost estimator's return.

Very interesting, said Sarah but this involves a huge amount of money that no cost estimator can afford. Peter replied: "Was I obliged to buy all the stock of the company when I used the butterfly spread?" Sarah concluded: "I see, the cost estimator can determine how much money he or she wants to bet and will get compensated accordingly."

But, exclaimed Sarah, what is going to happen if the estimator is capable of affecting the final cost of the project? (This question was suggested by one of the anonymous reviewers.) Peter said: “This would look like to the Enron scandal. The model is appropriate for estimators who have neither stake nor a responsibility in the implementation of project.”

SOME THEORETICAL AND PRACTICAL ISSUES

From a theoretical perspective, the compensation of cost estimators can be viewed as a principal-agent problem. The principal-agent problem arises in every situation where one person (the principal) hires another person (the agent) to perform some service on his behalf, and when there are a conflict of interests and asymmetrical information (Jensen and Meckling 1976). The standard agency model of incentives is concerned with the optimal contract that a principal must choose to induce the best effort from the agent. When the outcome depends on extraneous factors, the agent will require a high-risk premium that may render the incentives unprofitable for the principal. An effective way of reducing risk of extraneous factors is to provide the agent with incentives schemes based on a fixed pay plus a contingent compensation (Milgrom and Roberts 1992).

The causes of the estimate inaccuracies are multiple and complex. Some causes are related to the skills and behaviour of the estimators. Others are exogenous and unforeseeable. The butterfly spread strategy provides cost estimators with just enough incentive to induce the adequate behaviour but not enough to make them assume unforeseeable risk. Intuitively, the model seems consistent with the standard agency model of incentives. It remains to be demonstrated mathematically how to design an optimal contract using a butterfly spread**.**

From a practical perspective, many issues must be resolved before implementing the model. One of these issues is whether the team’s members should be rewarded individually or as a group. How the distribution of rewards should be structured to reflect the different level of risk assumed by each individual? Another issue is related to the elapsed time between the estimate date and the project completion. Delaying gratifications until the actual cost is known makes no sense especially for projects that take several years to complete. How does one determine when the distribution of rewards is effective in order to induce the expected behaviour?

REFERENCES

Black, F and Scholes, M (1973) The Pricing of Options and Corporate Liabilities. *Journal of Political Economy*, **81(**May–June), 593–616.

Flyvbjerg, B, Skarmus, M and Buhl, S (2002) Underestimating cost in public works projects: Error or Lie? *Journal of the American Planning Association*, **68**(3), 279–96.

GAO (2004) NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management, GAO-04-64, Washington, DC.

Garvey, P R (2000). *Probability methods for cost uncertainty analysis: a systems engineering perspective.* New York: Marcel Dekker.

Haug, E G (1997) *The Complete Guide To Option Pricing Formulas*. McGraw-Hill

Holm, L (2005) *Construction cost estimating: process and practices*. Upper Saddle River, NJ: Pearson/Prentice Hull.

Hull, J C (2002) *Options, Futures, and Other Derivatives*. 5ed. Upper Saddle River, NJ: Prentice-Hall.

Jensen, C J and Meckling, W H (1976) Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics*, **3**(4): 305–60.

Mackie, P and Preston, J (1998) Twenty-one sources of error and bias in transport project appraisal. *Transport Policy*, **5**(1), 1–7.

Mackie, P and Preston, J (1998) Twenty One Sources of Error and Bias in Transport Project Appraisal. *Transport Policy*, **54**(1), 1–7.

McMillan, LG (2002) *Options As a Strategic Investment*. 4ed. New York: New Yor Institute of Finance.

Milgrom, P and Roberts, J (1992) *Economics, Organization, and Management*. Englewood Cliffs, NJ: Prentice Hall.

NEWLY EQUITIZED CONSTRUCTION SMES IN VIETNAM: PROBLEMS AND SOLUTIONS

Quan T Nguyen,[1,2] Christopher N Preece,[1] Tam V Tran[2] and Steven Male

[1]*School of Civil Engineering, Univerity of Leeds, Leeds, LS2 9JT, UK*
[2]*Faculty of Construction Economics, National University of Civil Engineering, Hanoi, Vietnam*

Hundreds of construction state-owned small and medium sized construction enterprises in Vietnam have been equitized to date. They have faced many post-equitization problems. However, researchers have focused mainly on the equitization process, with limited research having been done on the post equitization period. A survey of 25 newly equitized construction SMEs using a qualitative triangulated research approach has been undertaken to address this gap. Five significant problems have emerged from the survey, which include both internal issues and problems created by external factors. Among the solutions that firms have applied, the enticement of a strategic investor may be considered as an appropriate option to sort out the internal problems. Also, firms should not stay passive and wait for the environment to change in their favour. Firms need to decide which solution(s) to apply as well as get involved in the process of making their business environment clear, clean and fair for their own benefits.

Keywords: construction companies, equitization, SMEs, Vietnam.

INTRODUCTION

"Equitization" is the official word that has been used instead of "privatization" in Vietnam. Aivazian *et al*. (2005) argues that privatization has been considered as a solution to sort out state-owned enterprises (SOEs)'s problem such as having "poor financial performance" (Bai *et al.* 2000) and this was not an exception in Vietnam. Hundreds of SOEs, including construction SOEs, have now been equitized, and most of them are small and medium sized enterprises (SMEs) (Dam 2004). Operating with the new structures, the newly equitized construction SMEs have faced many problems – post-equitization problems. However, literature shows that researchers have focused mainly on the equitization process, not on the post-equitization period. During the survey for this research, respondents (selected from the top managers of newly equitized construction SMEs in Vietnam) strongly explored their concerns about their firm's post-equitization problems. Most of them were very perplexed in finding a good way for their firms to develop strongly after equitization.

This paper focuses on the problems arising after construction SMEs equitized and discusses the possible solutions that firms can consider to sort out these problems.

For this purpose, the research commented by searching answers from theories of the firm and work on SMEs (Hoorn 1979; Hillebrandt and Cannon 1990; Keysey and Watson 1993; Hall 1995), strategic management (Stacey 1993; David 2001; Campbell *et al*. 2002; Burnes 2004) and strategic management in construction (Betts and Ofori 1999; Chinowsky and Meredith 2000; Langford and Male 2001). Then it was decided

[1] cenqnt@leeds.ac.uk

that most of these theories had originated in western capitalist societies and business schools and a more localized model of business/strategic management in SMEs had to be constructed from indigenous sources and fieldwork to reflect an emerging socialist market economy that had only recently moved from a command control structure. However, a review of privatization in other transition economies shows that there have been similar challenges for SMEs in these countries. The similarities are discussed below, together with the findings in newly equitized construction SMEs in Vietnam.

CONSTRUCTION SMES AND EQUITIZATION IN VIETNAM

Construction SMEs in Vietnam: classification

The term “enterprise” in Vietnam refers to “an economic unit that independently keeps business account and acquires its own legal status” (GSO 2005). They can be considered as state-owned enterprises, non-state enterprises or foreign direct invested enterprises. SOEs include enterprises with 100% of state capital or joint-stock companies with domestic capital, of which the Government holds more than 50% shares (GSO 2005). Only firms with 100% of state capital could be “equitized”.

Construction enterprises include enterprises that have registered and operate construction activities as their core business. They are often referred to in Vietnam as “contractors in construction activities” (National-Assembly 2004) or “contractors” for short. They are dispersed under many government management agencies, which include the Ministry of Construction, other ministries with specialized construction projects and local authorities.

Regarding the size of firms, if a firm has either registered capital less than 10 billions Vietnam Dong (approximately £320,000, exchange rate as at January 2007) or less than 300 employees, it can be considered as a small and medium sized enterprise (SME). There is no specific definition for a construction SME in Vietnam but construction SMEs in Vietnam account for over 90% of the whole construction firms if classified by size of labour force (Gso 2005).

This paper only focuses on the small and medium sized state-owned construction companies that have been equitized during the last 10 years.

Definition of equitization

Equitization in Vietnam is defined as “the transformation of SOEs into joint-stock companies and selling part of the shares in the company to private investors” (Truong 2006). This movement aims to (Government 2002):

- Improve the performance and competitiveness of enterprises by ownership diversification, with involvement of workers as shareholders; thus creating a dynamic management mechanism.
- Mobilizing capital from employees and outside domestic and/or foreign investors, for technology improvement and enterprises’ development.
- Balancing interests of the stakeholders in the equitized enterprises.

That is to say, equitization in Vietnam differs from privatization in the usual western sense in that it does not tend to reduce the state shares in the economy as a whole. It aims to sort out the difficulties for capital and mechanisms for state-owned companies. Another difference is that employees and managers of the firms can get a significant portion of shares in the newly equitized firms (Truong 2006).

Methods to equitize SOEs in Vietnam and the equitization process in construction sector

There are four methods to equitize a SOE in Vietnam (Government 2002; Truong 2006; Vu 2006):

- Keeping the state shares intact and issuing additional shares.
- Selling a fraction of the existing state shares.
- Selling of all existing state shares to workers and private shareholders (mostly applied to loss-making SOEs).
- Selling a fraction or all state shares and issuing new shares concurrently.

According to Truong (2006), the equitization process in Vietnam falls into two stages: the pilot stage from 1992–1996 and the expansion stage from 1996 up to now. Vu (2006) detailed the process into four stages: voluntary stage (6/1992–4/1996); expansion of the pilot programme (5/1996–5/1998); acceleration of the equitization programme (6/1998–5/2002); and continuing with the equitization programme (up to now). Nevertheless, in the construction sector, there were no construction firms equitized from 1992 to 1996. Until the period 1997–2001, the Ministry of Construction had to force 16 firms to equitize. However, since 2002, the pace has speeded up. In 2003 and the first 8 months of 2004, 82 construction firms that belong to the Ministry were equitized successfully. Most of them are SMEs. Now the number of equitized firms has reached hundreds. The newly equitized construction firms report that their ratio per registered capital reached 45.2% in comparison to 8.37% before equitization, average dividend is 24.3% (about three times greater than saving interest) (Dam 2004). That is to say, equitization has brought construction SOEs many successes. However, this paper only discusses the problems arising in the period of post-equitization for the newly equitized construction SMEs.

RESEARCH METHODS

The research question and the research approach

The research question driving this study is: “What are the problems of newly equitized construction SMEs in Vietnam and how firms confront with them?” It forms part of a research problem on construction SMEs’ strategic management that is using the same survey. The respondents were selected from top managers of construction state-owned SMEs that have been equitized over the last 10 years. The interviewees include members of the directorial boards (directors/general directors or vice directors/vice general directors depending on how a firm named the positions), other members of the management boards who are section managers and involved in the long-term decision making of the firms.

A qualitative triangulated research approach was used. In addition to undertaking direct interviews by the researcher, questionnaires were sent out through the researcher’s network of contacts who were working in the industry. Also, other available sources of data such as internship reports by student-trainees, annual reports as well as other accessible documents from the selected firms have been used to enrich the data. Other researchers’ works on the similar topic are also referred to when appropriate.

Fieldwork

The survey upon which this study is based covered the newly equitized state-owned construction SMEs in the two economic centres of the country: Hanoi and Ho Chi Minh City. For the broader research, approximately 70 construction SMEs out of a population of about 160 firms being contacted have participated in the survey, including interviews and questionnaires. Among them, 25 firms were newly equitized construction SMEs. The data for this research came from these 25 companies. Table 1 illustrates the structure of the survey sample.

Table 1: Structure of the survey sample

	Local or Central		Region		Respondent type		Data collection type		Total
	Local	Central	North	South	Directorial Board	Section Managers	Int	Ques	
In number	8	17	20	5	12	13	15	10	25
In %	32	68	80	20	48	52	60	40	100

Note: Int, Ques: survey done by interviewing and questionnaire completion respectively.

The survey was conducted using a set of ten major topics as guidelines. These were the basis of ten initial questions, designed to secure open answers and forming the interview questionnaire. The first questionnaire was constructed in English and needed translating into Vietnamese. To avoid using academic terms, the Vietnamese version was piloted with two respondents who worked as section managers in two construction firms (who were not familiar with academic terminologies). More detailed questions have also been asked for in-depth information when the interviewer thought necessary.

A mailed questionnaire was developed from the interview questions, which included the ten initial questions and the detailed questions raised in the context of the first five interviews. Many open-ended questions were added to avoid missing any valuable information.

Among the firms that participated in the survey, there were some firms where the state-owned share accounted for 51%, some where the state-owned share is less than 51% and there was one firm with the state-owned share reduced to 0% (fully privatized). Some respondents refused to mention the state-owned share in their firm, and the percentage of each type could not be fully worked out.

RESULTS AND DISCUSSIONS

According to the survey, the most noteworthy problems that newly equitized construction SMEs in Vietnam have faced fall into five categories:

- Lack of capital capability.
- Ineffectiveness in corporate management.
- Lack of properly competent human resources.
- The asynchrony and incompletion of the legislation system.
- External social issues, such as corruption and discrimination against newly equitized firms.

Among these five categories, the first three have been grouped as internal problems, while the last two could be considered as problems created by external factors.

However, the external environment also impacts on firms and therefore influences the so-called “internal problems”.

One can easily notice that the internal problems mentioned above are not unique to newly equitized construction SOEs in Vietnam. Literature shows that these problems have happened to SMEs in other countries, including SMEs in construction (Hoorn 1979; Birley 1989; Keysey and Watson 1993; Hall 1995; Dansoh 2005).

There are also other problems that have been mentioned in the survey. They include lack of a strong brand name, obsolete technology, clients’ delay in payment for finished projects. A strong brand name might be achieved when the firm is well managed and their management board is aware of developing its long-term value (Huynh 2005). This problem could be categorized into the second category. Due to the fact that most of the construction works or projects that this type of firms are involved in are not very complex, and do not required very modern technologies, many respondents agreed that obsolete technology is not as critical as the five problems listed above. There are several reasons that lead to the delay of clients in payment, such as the complication of payment procedures, distribution mechanism of state budgets etc.

The following paragraphs will discuss these problems and how firms have confronted them.

Lack of capital capability

To carry out their construction projects, firms in Vietnam, including the newly equitized SMEs, need working capital. They have to pay for labour costs, materials, rent of construction equipment if any, etc., before getting payment from their clients. The most important source for this is payments from clients for completed construction works or projects. Traditionally, construction SOEs consider the Government as their biggest client. However, in projects funded by the state budget, the payment process is very slow due to complicated administrative procedures. Sometimes, particularly in provinces, the funds that have been distributed to the local budget within a financial year is insufficient for all of the projects to run, so the management agencies need to select some projects to pay, perhaps randomly, and delay payments to others into another financial year. The delay in payment has sometimes changed a profitable project in to a loss making one. Possessing a small amount of capital, like in other countries (Keysey and Watson 1993), newly equitized construction SMEs found it very difficult to secure enough capital not only to run projects, but also to re-invest to develop. Therefore, firms have had to find other ways to solve this problem.

The solutions that have been applied by participating firms in the survey can be divided into two groups: short-term and long-term. The short-term solutions include mobilization of capital from available sources. However, banks, which might have been considered as the most convenient source of lending in other countries, are not that easy for securing funds in Vietnam. Since being equitized, SOEs have lost their priority in borrowing money from the state commercial banks, credit and financial institutions. They have to follow banks’ stricter rules with smaller lines of credit because they are not supported completely by the Government as before. In other words, the banks’ view on their reliability has been reduced. An alternative, to borrow from private or foreign-investment banks, is not seen as a good solution, because firms find it difficult to present a feasible study/report to persuade the banks due to the characteristics of construction works and the firms’ human resources’ competence.

Firms have to find other short-term solutions such as borrowing from their employees, shareholders and even from relatives and friends of the firms' management boards or project managers. Some project managers had to mortgage their family's assets to get money for their own "project-in-charge". That is to say, these sources are limited, not stable and sometimes very costly.

The considered long-term solutions include listing in the stock market, land development, business diversification and client selection. Twenty-one firms in the survey would not consider the first option until ten years later because they thought the stock market in Vietnam has not been well developed. Only one firm has put it into their five-year plan. Some firms inherited land from the pre-equitized state-owned company and considered the second option to utilize as their advantage by developing investment projects for real estate development. Some of them have turned to the client side and now employ other firms as contractors or do the construction works themselves (thus creating jobs). However, after some years, the real estate market in Vietnam has been slowing down, and many land development investment projects have been delayed.

Business diversification is another option that more than half of the surveyed firms have applied. Some of the firms have developed other businesses within the construction industry, such as providing consultancy or design services. Others bid for other types of projects such as irrigation, traffic and industrial work. Some undertake trading in construction materials and some trade in consumer and industrial products or supply services such as tourism, transportation and export-import. However, they admit that such kinds of diversification have brought with them many other problems and have not been as effective as they expected.

The last option can be considered as a long-term as well as short-term solution. Instead of bidding for every project that a firm can undertake, firms have taken account of the capital capability of the client into their consideration before getting involved into the projects they offer. Some firms, particularly firms from the South have even focused on foreign direct investment projects only, they have said they rarely bid now for state-funded projects. However, FDI projects are not completely safe. The public media have reported some foreign investors or main contractors' delaying payments or refusing payments to their domestic (sub)contractors (MOI 2004).

Ineffectiveness in corporate management

The problem of ineffectiveness in corporate management has been considered the most critical in the newly equitized firms in the survey. Results from the survey shows that this results from three major issues: top managers' lack of managerial skills, mechanisms for decision-making in firms and psychological barriers.

According to Huynh (2005), the managerial skills of a firm depend on two factors: the internal relationships (corporate culture, human resource competences); management techniques and technologies in use. The first factor will decide what kind of management techniques and technologies should be applied into the firm. It is the fact that management techniques and technologies are available from textbooks and business schools. However, most of the top managers of state-owned construction SMEs in Vietnam have been promoted from a technical background. Though some of them have attended several management or economics courses, they often use their own experiences in their new management position. About 60% of the top managers participating in the survey admitted spending much of time on doing professional tasks or checking their staff's work, such as estimations or tender documents due to the fact that they are not at ease with delegating to their staff.

In theory, after equitization, the managerial capability of a firm should be improved due to the involvement of many shareholders. Actually, this is not completely correct. Several reasons have been mentioned by respondents. Most of the shareholders holding small shares are not aware about their rights and therefore never get involved in the decision making process. In addition, the equity in most construction SMEs is highly closed to internal staff. Shares have been concentrated into a group of people that include top managers and their friends and relatives. This situation is similar to the "insider privatization" in Russia, Czech Republic, Hungary and Poland and in Asian countries, including Mongolia and China (summarized by Li and Rozelle 2004). As a result, the people that can have strong effects to the firms' decision remain unchanged. The change in managerial capability, therefore, is very limited. In addition, the internal equity in construction SMEs sometimes leads to the firm's unity being broken. There have been some conflicts/complaints or even lawsuits have happened in newly equitized firms. It has weakened the managerial capability of the firm.

Respondents, mostly from firms with more than 50% state share, claimed the firm's status as one of "new container but same spirit" after equitization. Actually, there is a resources limit in the governmental agencies in charge of the state shares in equitized firms. The people in charge of the state shares in the firms sometimes use their rights to veto important investment and management decisions that most of the shareholders agree with due to the fact that they want to conserve the state capital they are obliged to look after. There is also a risk for them that the administrative command from the line management agency can remove him/her from their current position.

All of the respondents in the survey were aware of their firms' situation and noted that in order to improve their corporate management skills, firms need to change. However, the best change to consider is to replace all of the top managers but the psychological barriers are among the significant obstacles to these changes. Some people in charge of state shares in firms do not want to take risks in order to retain their "chair at the table". This is similar to the situation in privatized Chinese firms. Senior managers do not have motivations to make any improvements because they do not have "cash flow rights" (Chen *et al*. 2006). Respondents claimed that some big shareholders do not want the change because it may threaten their rights and profits. Some are noted as simply lazy and do not want to spend time for new approaches when they think the old ones are still in order. In firms with problems of unity, people are too busy with sorting those issues out and do not have time to even think of change.

Firms facing these problems in the survey are still using many of their own solutions, but they admitted that they need a better way. A suggestion by Huynh (2005) is to secure a strategic investor, which can be an individual or an organization; this may be a good answer. According to him, a strategic investor needs to be able to:

- Recognize the long-term development trend of a firm and can help to develop a long-term strategy.
- Have strong financial capability or ability to mobilize investment capital.
- Have suitable managerial skills.
- Know about technology.

- Have the ability to expand the firm’s market.

In consideration of this long-term solution, top managers and shareholders in the firm need to admit to having to share their rights, interests, profits and obligations with the new shareholder. If a strategic investor is selected carefully, this solution may help sort out the first problem as well. In fact, in 12 newly equitized SMEs that are members of a corporation or holding company, the corporation or mother-company has been selected as the strategic investor. However, firms may still face the same problem of “new container but the same spirit” as mentioned above.

Lack of properly competent human resources

Most of respondents claimed that their human resources do not have rational competencies or their firms do not have enough staff that can do the job well. The most of quoted reason for that is they cannot compete with larger companies in luring competent staff through salaries or other benefits due to their limited resources. However, there are several solutions that firms have applied.

Some firms only pay attention to a few key people, such as the section managers and project managers (or site managers in construction sites). Since they are SMEs, their structure is often very compact (Birley 1989; Ackroyd 2002). They then empower project managers to employ their own engineers and technical/professional people. They apply the “*khoan* mechanism” – one kind of subcontract between the firm and their teams, in which the firm takes a percentage of the contract value and lets the team(s) manage the remaining. The team can take all the profit within the certain amount of money that they receive from a “khoan” contract. By that mechanism, project managers may have more funds to provide more benefits for their own staff and can secure competent staff. Others apply a training-on-site programme for staff, especially newly employed engineers and workers. They claim that by this programme, they have a reserve of competent staff for the next part of a project or new projects. Some firms apply both solutions. Nevertheless, firms still claim that they are lacking in competent human resources. To solve this problem completely, they may need to develop and/or need a long-term strategy/policy. A strategic investor’s involvement may be a good solution to this.

The asynchrony and incompletion of the legislation system

This issue, in one aspect, can reflect the economic mechanisms of the country. This is an external factor that firms cannot impact on directly. They have to cope with the fact that regulations change very fast and often overlap one another, and different regulations can be issued by different governmental organizations. Some respondents claim that a decision or an ordinance has just been issued; and firms have not been able to learn about it quite before another issuance is released to replace the old one. Some regulations issued by local governmental agencies conflict with those issued by the central governmental bodies. Some laws or decrees had been issued for a long time, but the supporting regulations and instructions remain in draft form. Firms have no way but to adapt to this. The most efficient way may be that firms set up a team to deal with this issue, as their second job, in order to update as soon as possible knowledge on new regulations and hence release this heavy burden from the top managers. However, the situation is improving. World Trade Organization membership has required that the country amends its legislative system to suit to the legitimate requirements from this organization. Respondents are expecting a clearer and more effective legislative system in the near future.

Impacts from external social issues

Discrimination of newly equitized firms, including construction SMEs still exists. The case of borrowing money from banks and financial institutions is a good example. Newly equitized construction SMEs find themselves suffering disadvantages in comparison to other state-owned companies. The state-owned companies get favourable conditions in land use rights, lower interest on borrowing money from the state commercial banks and financial institutions. They can borrow from the bank without mortgaging their assets, but use their prestige as a state-owned company only. Their debt is easily delayed or cleared when they have trouble in payment. After equitization, firms lost most of these favourable conditions. For instance, they have to mortgage their land to get money from the bank. Nevertheless, some firms do not have the rights to use the land for that purpose because they have not been transferred from the local government agencies (number of respondents admitted=3). Respondents claim that their firms face also discrimination in dealing with the administrative procedures when they have to work with governmental organizations. However, the environment has been improving. Discrimination has been made more aware publicly and has been cleared out on a step-by-step basis by new regulations and laws. This problem is related to the previous problem.

Corruption is a major problem, especially in the construction sector where the majority of invested capital comes from the state budget. This is a problem not only for the newly equitized SMEs, but also all the firms that operate in the sector. In some state-funded projects, particularly projects at the local level, the Government representatives in charge of issuing the decision for construction contracts always give their favour to the firm that may give them back the highest commission. The public newspapers have reported many cases in the period from 2004 to 2006. Respondents admitted that this type of “lubricant cost” is a problem for their firms. This makes the competition unfair, and firms have to find mechanism to make this expense official under other expenses. Another negative consequence is firms have to reduce the quality level on projects, and cutting expense to recover the cost. Vietnamese society in general is more aware of this and things would appear to be changing. The completion of the legislative system can help reduce this. In addition, the emergence of new markets for firms to compete in such as the foreign investment and the private sector gives them more options to avoid being involved in corrupt practices. Last but not least, construction firms now are aware of building up their brand name; therefore they pay more attention to quality and avoid risks of involvement in problems such as corruption.

CONCLUSIONS

Since the period 1997–2001, when 16 construction enterprises were equitized, the number of equitized construction SOEs, including SMEs has increased significantly. Besides the many advantages that equitization has brought, this paper has presented research that has highlighted newly equitized SMEs in construction in Vietnam have also faced many problems. The most significant problems include lack of capital capability; ineffectiveness in corporate management; lack of properly competent human resources; the asynchrony and incompletion of the legislative system; and external social issues, such as corruption and discrimination against newly equitized firms. These five problems have been classified as internal problems (the first three) and problems created by the external environment (the last two).

The firms that have participated in the research have applied several solutions, both short-term and long-term to help solve these problems. However, one solution has emerged that may be considered to help sort out all the internal problems: the enticement of a strategic investor into the firms. Though respondents agree about the importance of a strategic investor, they remain afraid of this type of involvement in their firms' operation and also what kind of strategic investor they should choose. More detailed research should be carried out to establish the answer to these questions.

To cope with the problems regarding the legislative system and the economic mechanisms of the country, firms have no option but to adjust themselves to it. A suggestion that may be useful is that firms need to update themselves very quickly with these changes in the improvement to the legislation system, need to remain aware of them, and avoid involving themselves in corrupt practices. Also, firms need to become involved in the process of making their business environment clear, clean and fair for their own benefits. To conclude, the firms themselves need to decide which solution(s) they should choose to solve their post-equitization problems.

REFERENCES

Ackroyd, S (2002) *The organization of business: applying organizational theory to contemporary change*. Oxford: Oxford University Press.

Aivazian, V A, Ge, Y and Qiu, J (2005) Can corporatization improve the performance of state-owned enterprises even without privatization? *Journal of Corporate Finance*, **11**(5), 791–808.

Bai, C-E, Li, D D, Tao, Z and Wang, Y (2000) A Multitask Theory of State Enterprise Reform. *Journal of Comparative Economics*, **28**(4), 716–38.

Betts, M and Ofori, G (1999) Strategic management in construction. *In:* M Betts (Ed.), *Strategic Management of IT in Construction*. Oxford: Blackwell Science Ltd.

Birley, S (1989) Corporate strategy and the small firm. *In:* D Ash and C Bowman (Eds.) *Readings in strategic management*. Basingstoke: Macmillan Education in association with the Open University.

Burnes, B (2004) *Managing change: a strategic approach to organisational dynamics*. 4ed. Harlow: Financial Times Prentice Hall.

Campbell, D, Stonehouse, G and Houston, B (2002) *Business strategy: an introduction*. 2ed. Oxford: Elsevier Butterworth-Heinemann.

Chen, G, Firth, M and Rui, O (2006) Have China's enterprise reforms led to improved efficiency and profitability? *Emerging Market Review*, **7**, 82–109.

Chinowsky, P S and Meredith, J E (2000) Strategic management in construction. *Journal of Construction Engineering and Management*, **126**(1).

Dam, H V (2004) Finding positive solutions for equitization. *In: Vietnameconomy*, Hanoi.

Dansoh, A (2005) Strategic planning practice of construction firms in Ghana. *Construction Management and Economics*, **23**(2), 163–8.

David, F R (2001) *Strategic Management: concepts and cases*. New Jersey: Prentice-Hall, Inc.

Government (2002) Decree on equitization of SOEs. *In: 64-2002/ND-CP*, Vietnam.

GSO (2005) *The real situation of enterprises through the results of surveys conducted in 2002, 2003, 2004*. Hanoi: Statistics Publishing House.

Hall, G (1995) *Surviving and Prospering in the Small Firm Sector*. London: Routledge.

Hillebrandt, P M and Cannon, J (1990) *The modern construction firm*. Basingstoke: Macmillan.

Hoorn, T P v (1979) Strategic planning in small and medium-sized companies. *Long Range Planning*, **12**(2), 84–91.

Huynh, T D (2005) The role of strategic investors in the equitization process of SOEs and the development of Vietnamese stock market, Ho Chi Minh City: Fulbright Economics Teaching Programme.

Keysey, K and Watson, R (1993) *Small firm management: ownership, finance, and performance*. Oxford: Blackwell Business.

Langford, D A and Male, S P (2001) *Strategic management in construction*. Oxford: Blackwell Science.

Li, H and Rozelle, S (2004) Insider privatization with a tail: the screening contract and performance of privatized firms in rural China. *Journal of Development Economics*, **75**(1), 1–26.

MOI (2004) Disputes between maincontractors and subcontractors - The foreign side owed the domestic contractor. *In: Business Forum*, Ministry of Industry Website.

National-Assembly (2004) Law on Construction. *In: 16-2003-QH11*, Vietnam, 3–4.

Stacey, R D (1993) *Strategic management and organisational dynamics*. London: Pitman Publishing.

Truong, D L (2006) *Equitization and Stock-Market Development: The Case of Vietnam*, PhD thesis, Economics, University of Groningen.

Vu, T T A (2006) Competition and Privatization in Vietnam: Substitutes or Compliments? *In: Vietnam Development Forum*, Tokyo, Japan.

FLEXIBILITY MANAGEMENT IN THE CHANGING COMPETITIVE ENVIRONMENT

Benson Lim,[1] Florence Ling and George Ofori

Department of Building, National University of Singapore, 4 Architecture Drive, 117566 Singapore

The ability to anticipate and respond to opportunities or pressure for changes, both internally and externally, is important to ensure competitiveness and sustainability of an organization. Flexibility management (termed as 'manufacturing flexibility in manufacturing research) is emerging as a key competitive strategy in response to the constantly changing competitive environment. Authors have attempted to relate the value of flexibility to crisis management, real option approach and human resource management in construction business. It appears, however, flexibility management is widely recognized as a multi-dimensional concept that is not being well-understood. The objectives of this paper are to: (1) review the fundamental principles of flexibility management; (2) consider its application in the construction industry; and (3) develop a conceptual model for delivering flexibility in the construction industry. The review shows that the major variables of manufacturing flexibility include business strategy, organizational attribute, supply chain relationship and technology. This research project is based on the premise that flexibility concept is applicable to the construction industry given that these key variables are comparable to those forming the competitive environment of the construction industry.

Keywords: competitiveness, management of change, management of firm.

INTRODUCTION

The cyclical nature of the construction industry coupled with the increasing level of foreign competition and changing expectations of customers have placed much stress on managerial personnel to find ways in surviving the changing competitive environment (Lansley 1983, 1987). Organizations cannot afford to wait until consequence of these changes become apparent but need to move from reactive tactics to anticipatory strategic planning to ensure its competitiveness and sustainability (McGregor 2000).

Flexibility management is emerging as a key competitive strategy in response to the constantly changing competitive environment (Oke 2005; Olsson 2006). Although the concept of flexibility management is well documented in the manufacturing literature (termed as manufacturing flexibility), little is known of its appropriateness within the context of construction industry in response to its competitive environment. Recognizing this gap, this research project will be conducted in five phases: (1) problem identification in the changing environment; (2) literature review of flexibility management in manufacturing and construction industry; (3) model design; (4) model testing; and (5) model validation. With respect to the first three phases of this research project, the objectives of this paper are to: (1) review the fundamental principles of

[1] g0500825@nus.edu.sg

flexibility management; (2) consider its application to the construction industry; and (3) develop a conceptual model for delivering flexibility in the construction industry.

WHAT IS ‘FLEXIBILITY’?

Gupta and Goyal (1989) defined ‘flexibility’ as the ability to cope quickly with changing circumstances and environmental uncertainty. Bucki and Pesqueux (2000) shared the view that being flexible allows organization to vary and adapt according to the environmental changes or organization’s needs and thus defined it as “the ability to adapt, in a reversible manner, to an existing situation, as opposed to evolution, which is irreversible” (2000: 62). However, some authors take the view that the term ‘flexibility’ should be orientated toward either a more operational or economic approach. From an operational perspective, Nagarur (1992) defined it as the ability of a system to quickly adjust or adapt to any changes in relevant factors like product, process, loads and machine failure. Das and Patel defined it as “the ability of a system or facility to adjust to changes in its internal or external environment” (2002: 266). Upton, however, perceived ‘flexibility’ in a more economic way, and defined it as “the ability to change or react with little penalty in time, effort, cost or performance” (1995: 207). Zhang *et al*. extended this definition and described ‘flexibility’ as “the organization’s ability to meet an increasing variety of customer expectation without excessive costs, time, organization disruptions or performance losses” (2003: 173).

Besides defining ‘flexibility’, authors (Evans 1991; Swafford *et al*. 2006) attempted to relate ‘flexibility’ to other resembling concepts; somewhat the notion of ‘agility’ is often used synonymously to ‘flexibility’. They described it as an ability to be nimble in moving into an advantageous position. Goldman *et al*. (1994) listed nine elements of organizational agility such as: (i) continuous improvement, (ii) changes and (ii) flexible. This assertion placed flexibility as a component to agility. Thus, it is recognized that organization needs to be flexible before attaining agility. There seems to be a common theme in all these definitions and concepts. The term ‘flexibility’ is defined in the research as the ability to respond or readapt, in a reversible, timely and appropriate manner to the changing competitive environment.

FLEXIBILITY MANAGEMENT IN MANUFACTURING AND ITS KEY ENABLERS

Flexibility management has been widely studied in the manufacturing literature (termed as manufacturing flexibility) over the past decades. Flexibility in manufacturing is seen as an integrative multi-dimensional concept rather an independent variable that can be defined and measured in isolation (Slack 1987; Beach *et al*. 2000). Many studies (e.g. Koste and Malhotra 1999; Koste *et al*. 2004) have attempted to identify various types of flexibility dimension such as: (i) volume; (ii) expansion; (iii) logistic; (iv) operation; (v) market; (vi) procurement; (vii) spanning; (viii) labour; (ix) process; (x) modification; (xi) program; (xii) financial; (xiii) material; (xiv) machine; and (xv) product. Despite these efforts in identifying various types of flexibility dimension, Oke (2005) observed that there is no general consensus of how flexibility should be determined. Also, he found that some reported empirical studies and analytical models of flexibility have the tendency to treat flexibility as a uni-dimensional concept. Slack (1983) suggested that an organization may exhibit its flexibility in many different ways. Some authors suggested that flexibility should be determined exclusively by the flexibility of an organization’s resources and processes (e.g. Slack 1987; Carlsson 1989) as well as its operating polices and management practices (Gupta and Buzacott 1989). Besides identifying and developing generic taxonomy of flexibility dimension, studies were conducted to investigate the relationship between different flexibility types and the influence of exogenous variables in the implementation of flexibility management in manufacturing (e.g. Pagell and Krause 2004).

Despite many works done on manufacturing flexibility concept, Beach *et al*. (2000) pointed out that little or no attention has been given to the method of acquiring those flexibility dimensions. Thus, they highlighted the need to investigate key enablers contributing the attainment of flexibility. They postulated that flexibility is a product of several enablers such as corporate culture, management structure, facility layout, information technology, process technology and human resource. Vokurka and O'Leary-Kelly (2000) hypothesized that the understanding of environmental factor with the integration of key enablers such as organizational attributes, business strategy and technology will lead to attainment of required flexibility. Kara and Kayis (2004) reinforced that labour, information technology, process technology and organization structure can be seen as the method for delivering flexibility.

Supporting some of the above propositions, some studies found that there is a negative relationship between firm's size and flexibility (Fiegenbaum and Karnani 1991; Das *et al*. 1993). Likewise, many studies have shown that business strategy is one of the key enablers in flexibility management (Gupta and Somers 1996; Vokurka and O'Leary-Kelly 2000). Different business strategies (e.g. low cost vs. differentiation strategy, defensive vs. offensive strategy, reactive vs. proactive) will call for different level of flexibility. Beach *et al*. (2000) suggested that future studies should consider the influence of corporate culture on the choice of strategy adopted toward the implementation of flexibility. Upton's (1995, 1997) studies showed that the extent of emphasis placed by managerial has positive impact on flexibility development.

Suarez *et al*. (1996) studied the effects of several managerial based policies (i.e. lean management, supply chain management) on three flexibility dimensions (i.e. volume, production, new design). They found that supplier involvement has a positive relationship on the three flexibility dimensions. Their finding was further substantiated by Chang *et al*.'s (2005) study that found that supplier involvement plays an important role in the development of a firm's flexibility and its performance. The implication of these two studies is that supply chain relationship has a major impact on the acquisition of flexibility. Also, Carlsson (1989) recognized that organization structure and people are the key determinants in flexibility management. In an open and flat organization, the chances of dealing successfully with adversities and uncertainties seem to be considerably greater than in a closed and rigid organization. Englehardt and Simmons (2002) found that a prevailing organizational challenge is to provide both structure and flexibility that suit this constantly changing environment. They recommended decentralization and flattening, matrix organizations and network organizations to enhance flexibility.

In addition to the above key enablers, Karuppan (2004) highlighted that human resource is the foundation in developing flexibility. She suggested that an organization should invest in balancing its employees' flexibility via training opportunities. Also, Crocitto and Youssef (2003) suggested that an appropriate (i.e. user friendly and compatible) information technology is also an essential component of flexibility. It facilitates the establishment of an effective communicating network among employers, employees, supply chain parties and customers. Likewise Correa (1994) discussed two different streams of process technology in improving flexibility i.e.: (i) flexible automation approach to modify process to changes and (ii) methodology based approach concentrates on the interaction of organization, human resources and conventional. Yadav *et al*. (2000) highlighted that process technology cannot itself contribute to flexibility. It should be accompanied by human resources, supplier relationships, market skills and training, and information technology to enhance its flexibility capabilities in response to a changing business environment. Sharing this view, Garcia and Turner (2006) highlighted that organizations need to be innovative in improving and creating their processes, and constantly appraise themselves against process improvement paradigm(s). Some examples of process improvement paradigm include: (i) Capability Maturity Model Integration (CMMI®) by Carnegie Mellon University and (ii) Organizational Project Management Maturity Model (OPM3) by Project Management Institute.

FLEXIBLITY MANAGEMENT IN CONSTRUCTION

The notion of learning from manufacturing industry is not new. Some successful examples of such learning are the application of various management concepts such as six sigma, just in time, lean production, supply chain and total quality management. Turning to flexibility management in construction, some researchers in the field of construction management have recognized the need for flexibility in order to survive the turbulent business condition (e.g. Lansley 1983, 1987). Lansley (1983) highlighted that the need for flexibility (an ability to realign existing resources to meet new demands) is accepted by most organizations, although the means for achieving flexibility remains elusive. Other studies (i.e. Lansley *et al*. 1974, 1975) on the development of conceptual models based on organization structure, management style and problem solving skill have been successful in describing the determinants of flexibility to practising manager. Based on these models, Lansley (1983) proposed a practical approach to auditing organization flexibility via identification and analysis of constraints. Following this, Lansley (1987) attempted to establish a link between the environment of the construction industry and the contractors' strategies by considering the differences in the nature of demand on construction organization over three decades of different business environments. He found that these environments required construction organizations to structure their operations in different ways where managerial staffs have to adopt different problem solving skills.

Other researchers have attempted to use flexibility as one of their measures on the prediction of organization effectiveness. Handa and Adas (1996) used the dimension of flexibility in two aspects: (i) structural context and (ii) rule and regulation. The former contains variables such as level of joint venturing, subcontracting and information flow. The latter consists of variables such as attitude towards change and level of process control. Dikman *et al*. (2005) used flexibility as an independent variable to measure effectiveness of construction organizations.

Besides organizational settings, flexibility concept has also been used in element-specific and project-oriented research in construction. For examples, Ofori and Debrah (1998) explored flexibility management of workers in Singapore. Their study provided a review of labour market flexibility and employment structure as well as a critique of flexibility model. They revealed that product-related organizations tend to reduce the number of their core employees and vary the number of their peripheral workers such as part-timers and temporary workers in response to production demand.

Gil *et al*. (2005) developed a framework on product and process flexibility to cope with challenging project deliveries.

There is a need for greater flexibility in presenting project information due to the diversity of people, organization and activities involved in the construction process (Betts 1991). Betts's study revealed that the use of relational database technology and integrate database design methodology improve the flexibility of information retrieval. Ekstrom and Bjornsson (2005) used the concept of real options to assess the value of flexibility in information technology investment. They found that it is possible to quantify the value of flexibility for information technology investment but the selection of measurement instrument is directly related to the nature of individual project. Ford *et al*. (2002) have also used the real options approach to ascertain strategic flexibility during project evaluation process. Their study revealed that the existing usage of flexibility in project management is not structured adequately to provide useful strategy design and valuation tool. They found that the use of real option approach in project evaluation would potentially increase project value by: (i) explicitly designing definite uses of managerial flexibility during projects and (ii) valuing the flexibility in pre-project planning.

Along the project flexibility domain, Walker and Shen (2002) explored the link between planning and flexibility towards good construction time performance through a framework of project understanding and knowledge transfer. They found that organization, team competence and commitment to exploring alternative options are the keys to good construction time performance. In order to respond to unanticipated challenges during the course of a project and succeed, the development of a learning culture that fosters flexibility within a systematic problem solving approach is necessary (Walker and Loosemore 2003). Their study revealed that this flexible approach could be achieved using a crisis management model. Interestingly, Olsson's (2006) study revealed that all the projects investigated by him had been actively involved in flexibility management across the project lifecycle.

CONCEPTUAL FRAMEWORK FOR DELIVERING FLEXIBILITY

Based on the above review, the importance of being flexible is well recognized within the context of both the manufacturing and construction industries. It appears, however, that the concept of flexibility in construction is fairly fragmented and not well-understood. Some researchers tend to perceive flexibility as a uni-dimensional construct rather than an integrative multi-dimensional concept. Also they tend to look specifically at individual elements such as information technology and human resource in attaining flexibility. Beside this, construction-related studies on flexibility tend to use project(s) as subject matter, but not considering a construction organization as unit of analysis. It is maintained that the emphasis should be placed on construction organization itself since the ability of being flexible involves the interdependency of various key enablers of an organization. For example, labour flexibility is dependent on flexibility of the organizational structure in which this flexibility capability will in turn influence the construction project delivery.

To achieve a better understanding of flexibility management for construction business in a changing competitive environment, a conceptual framework for delivering flexibility is developed (see Figure 1). It is hypothesized that flexibility management comprises eight key enablers: (i) supply chain relationship; (ii) organizational culture;

(iii) human resource; (iv) business strategy; (v) information technology; (vi) process technology; (vii) firm size; and (viii) organizational structure. Likewise, flexibility is operationalized into 15 dimensions: (i) volume; (ii) expansion; (iii) logistic; (iv) operation; (v) market; (vi) procurement; (vii) spanning; (viii) labour; (ix) process; (x) modification; (xi) program; (xii) financial; (xiii) material; (xiv) machine; and (xv) product.

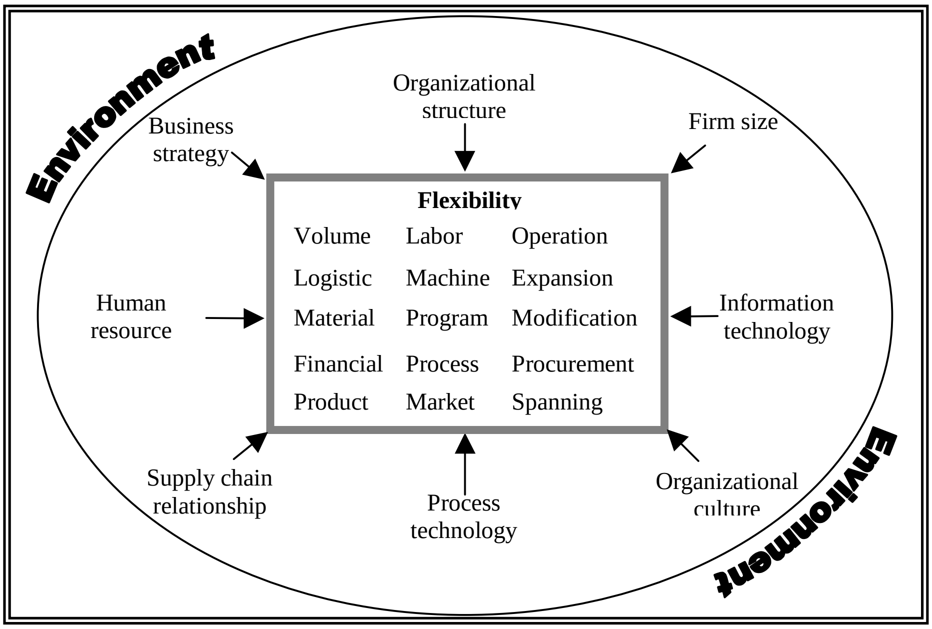


Figure 1: Conceptual model for delivering flexibility in a construction organization

THEORETICAL FOUNDATION ON FLEXIBILITY MANAGEMENT

Within the context of a construction organization, both complexity theory and resource based theory (RBT) corresponding to “how organization behaves” and “how organization competes” in response to a changing environment form the theoretical foundation of this research. Complexity theory presumes organization as an adaptive system that comprises a complex linkage of elements that behaves in line with its environment and ultimately emerges into a higher performance entity (Tetenbaum 1998). Likewise, RBT presumes an organization as a collection of unique resources and capabilities that provides the basis for its strategy and the primary source of its return (Grant 1991).

It is recognized that a construction organization should be analyzed as a single entity that is heavily linked with many interactive elements (nodes), which is determined to a great extent by an organization’s resource and capabilities. In this case, the nodes will represent the key enablers in delivering flexibility (Figure 2a). Figure 2b illustrates the exertion of an external force (e.g. changes, chaotic event happened) on the organization system. This external force will reshape the structure of those elements (e.g. human resource, organization structure and technologies) within the organization system with the resultant system that reacts adaptively in dynamic way as illustrated in Figure 2c. In the face of any event, the linkages between the nodes (i.e. resource and capabilities) denote the level of flexibility within an organization.

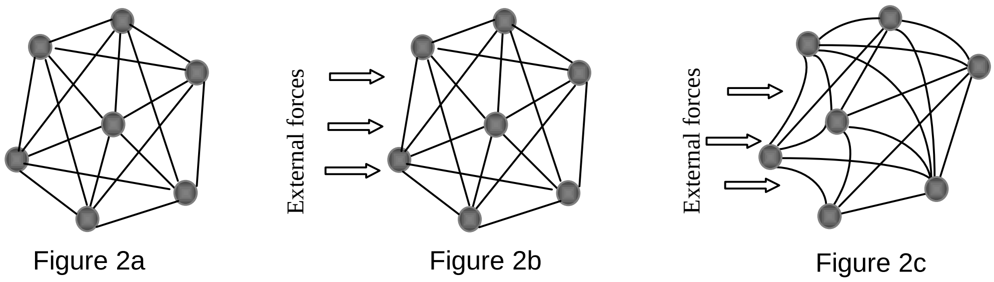


Figure 2: Organization as an adaptive system to the changing environment

FUTURE DATA COLLECTION EFFORT

The conceptual model (Figure 1) would be subjected to testing and validation. A two-phase data collection process is proposed. Phase I involves conducting semi-structured interviews with three experts from the industry. The purpose is to uncover the languages and terms associated with the flexible concept. Phase II involves the investigation of contractors' flexibility management by conducting an industry-wide survey. Survey questionnaire is formulated based on results of semi-structured interviews and literature review. The aims of survey are twofold: (i) to ascertain the importance of key enablers in the proposed conceptual model; and (ii) to confirm enablers lead to flexibility and thus achieve better organization's performance. Prior to the actual run, a pilot test shall be conducted to test clarify of survey questionnaire.

Given that the size of firm is a key enabler in flexible management, the target group of large and medium sized general building contractors (Group A1, A2, B1 and B2) will be selected from the contractors' registry of the Singapore Building Construction Authority (BCA). These four targeted groups are categorized in accordance to their financial grade under the BCA contractors' registry (see http://www.bca.gov.sg). To enhance the validity of this study, we attempt to refine the sampling frame by comparing the list of registered contractors between the year 1999 (a year after Asian Financial Crisis) and 2007 where those contractors who still appear in the list as of 2007 will be contacted. This is based on the belief that these contractors have executed some flexibility measures in riding the wave of changes over the periods of recession in the local construction industry. In the analysis stage, a structural equation modelling technique could be used to analyse the interrelationship of each key enablers towards the attainment of flexibility.

CONCLUSION

In undertaking the initial stage of this research, flexibility management is seen as a necessity in the constantly changing competitive environment. Judging from the manufacturing literature, construction industry is still far from attaining a full understanding and adoption of flexibility management. From the review of literature, it was found that key enablers to flexibility are: (i) supply chain relationship; (ii) organizational culture; (iii) human resource; (iv) business strategy; (v) information technology; (vi) process technology; (vii) firm size; and (viii) organizational structure. These key enablers form the conceptual framework that may be used by organizations to achieve flexibility. Likewise flexibility is operationalized into 15 dimensions: (i) volume; (ii) expansion; (iii) logistic; (iv) operation; (v) market; (vi) procurement; (vii) spanning; (viii) labour; (ix) process; (x) modification; (xi) program; (xii) financial; (xiii) material; (xiv) machine; and (xv) product.

REFERENCES

Beach, R, Muhlemann, A P, Price, D H R, Paterson, A and Sharp, J A (2000) A review of manufacturing flexibility. *European Journal of Operational Research*, **122**(1), 4–57.

Betts, M (1991) Achieving and measuring flexibility in project information retrieval. *Construction Management and Economics*, **9**(3), 231–45.

Boyle, T A (2006) Towards best management practices for implementing manufacturing flexibility. *Journal of Manufacturing Technology Management*, **17** (1), 6–21.

Bucki, J and Pesqueux, Y (2000) Flexible workshop: about the concept of flexibility. *International Journal of Agile Management System*, **2**(1), 62–70.

Carlsson, B (1989) Flexibility and the theory of the firm. *International Journal of Industrial Organization*, **7**(2), 179–203.

Chang, S C, Chen, R H, Lin, R J, Tien, S W and Sheu, C (2006) Supplier involvement and manufacturing flexibility. *Technovation*, **26**(10), 1136–46.

Correa, H L (1994) The flexibility of technological and human resources in automotive manufacturing. *Integrated Manufacturing System*, **5**(1), 33–40.

Crocitto, M and Youssef, M (2003) The human side of organizational agility. *Industrial Management & Data Systems*, **103**(6), 388–97.

Das, B J, Chappell, W G and Shughart, W F (1993) Demand fluctuations and firm heterogeneity. *Journal of Industrial Economics*, **41**(1), 51–60.

Das, S K and Patel, P (2002) An audit tool for determining flexibility requirements in a manufacturing facility. *Integrated Manufacturing Systems*, **13**(4), 264–74.

Dikmen, I, Birgonul, M T and Kizitas, S (2005) Prediction of organization effectiveness in construction companies. *Journal of Construction Engineering and Management*, **131**(2), 252–61.

Englehardt, C S and Simmons, P R (2002) Organizational flexibility for a changing world. *Leadership & Organizational Development Journal*, **23**(2), 113–21.

Ekstrom, M A and Bjornsson, H C (2005) Valuing flexibility in architectural, engineering, and construction information technology investment. *Journal of Construction Engineering and Management*, **131**(4), 431–8.

Evan, J S (1991) Strategic flexibility for high technology manoeuvres: a conceptual framework. *Journal of Management Studies*, **28**(1), 69–89.

Fiegenbaum, A and Karnani, A (1991) Output flexibility – a competitive advantage for small firms. *Strategic Management Journal*, **12**(2), 101–14.

Ford, D N, Lander, D M and Voyer, J J (2002) A real options approach to value strategic flexibility in uncertain construction projects. *Construction Management and Economics*, **20**(4), 343–51.

Garcia, S and Turner, R (2006) *CMMI® Survival guide: just enough process improvement*. Boston: Pearson Education Inc.

Gil, N, Tommelein, I D, Stout, A and Garrett, T (2005) Embodying product and process flexibility to cope with challenging project deliveries. *Journal of Construction Engineering and Management*, **131**(4), 439–48.

Goldman, S L, Nigel, R N and Preiss, K (1995) *Agile competitors and virtual organizations: strategies for enriching the customer*. New York: Van Nostrand Reinhold.

Grant, R M (1991) The resource based theory of competitive advantage: implications of strategy formulation. *California Management Review*, **33**(3) Spring, 114–35.

Gupta, Y P and Somers, T M (1996) Business strategy, manufacturing flexibility, and organizational performance relationships: a path analysis approach. *Production and Operations Management*, **5**(3), 204–33.

Gupta, Y P and Buzacott, J A (1989) A framework for understanding flexibility of manufacturing system. *Journal of Manufacturing System*, **8**(2), 89–97.

Gupta, Y P and Goyal, S (1989) Flexibility of manufacturing systems: concepts and measurement. *European Journal of Operational Research*, **43**(2), 119–35.

Handa, V and Adas, A (1996) Predicting the level of organizational effectiveness: a methodology for the construction firm. *Construction Management and Economics*, **14**(4), 341–52.

Kara, S and Kayis, B (2004) Manufacturing flexibility and variability: an overview. *Journal of Manufacturing Technology Management*, **15**(6), 466–78.

Karuppan, C M (2004) Strategies to foster labour flexibility. *International Journal of Productivity and Performance Management*, **53**(6), 532–47.

Koste, L L and Malhotra, M K (1999) A theoretical framework for analyzing the dimension of manufacturing flexibility. *Journal of Operations Management*, **18**(1), 75–93.

Koste, L L, Malhotra, M K and Sharma, S (2004) Measuring dimension of manufacturing flexibility. *Journal of Operations Management*, **22**(2), 171–96.

Lansley, P R, Sadler, P and Webb, T (1974) Organization structure, management style and company performance. *Omega*, **2**(4), 468–85.

Lansley, P R, Sadler, P and Webb, T (1975) Organization structure, management style and company performance: some recent results. *Omega*, **3**(5), 615-17.

Lansley, P R (1983) A practical approach to auditing organizational flexibility. *Construction Management and Economics*, **1**(2), 145–56.

Lansley, P R (1987) Corporate strategy and survival in the UK construction industry. *Construction Management and Economics*, **5**(2), 141–51.

McGregor, W (2000) Preparing for an uncertain future. *Facilities*, **18** (10-12), 402–10.

Nagarur, N (1992) Some performance measures of flexible manufacturing systems. *International Journal of Production Research*, **30**(4), 799–809.

Ofori, G and Debrah, Y A (1998) Flexible management of workers: review of employment practices in the construction industry in Singapore. *Construction Management and Economics*, **16**(4), 397–408.

Olsson, N O (2006) Management of flexibility in projects. *International Journal of Project Management*, **24**(1), 66–74.

Oke, A (2005) A framework for analysing manufacturing flexibility. *International Journal of Operations & Production Management*, **25**(10), 973–96.

Parker, R P and Wirth, A (1999) Manufacturing flexibility: measures and relationships. *European Journal of Operational Research*, **118**(3), 429–49.

Pagell, M and Krause, D R (2004) Re-exploring the relationship between flexibility and the external environment. *Journal of Operations Management*, **21**(6), 629–49.

Slack, N (1983) Flexibility as a manufacturing objective. *International Journal of Operations and Production Management*, **3**(3), 5–13.

Slack, N (1987) The flexibility manufacturing systems. *International Journal of Operations and Production Management*, **7**(4), 35–45.

Suarez, F F, Cusumano, M A, Fine, C H (1996) An empirical study of manufacturing flexibility in printed circuit board assembly. *Operations Research,* **44**(1), 223–40.

Swafford, P M, Ghosh, S and Murthy, N (2006) The antecedents of supply chain agility of a firm: scale development and model testing. *Journal of Operations Management*, **24**(2), 170–88.

Tetenbaum, T J (1998) Shifting paradigms: from Newton to chaos. *Organizational Dynamics*, **26**(4), 21–32.

Upton, D M (1995) Flexibility as process mobility: the management of plant capabilities for quick response manufacturing. *Journal of Operations Management*, **12**(3–4), 205–24.

Upton, D M (1997) Process range in manufacturing: an empirical study of flexibility. *Management Science,* **43**(8), 1079–92.

Vokurka, R J and O'Leary-Kelly, S W (2000) A review of empirical research on manufacturing flexibility. *Journal of Operations Management*, **18**(4), 485–501.

Walker, D H T and Loosemore, M (2003) Flexible problem solving in construction project on the National Museum of Australia project. *Team Performance Management: An International Journal*, **9**(1–2), 5–15.

Walker, D H T and Shen, Y J (2002) Project understanding, planning flexibility of management action and construction performance: two Australian case studies. *Construction Management and Economics,* **20**(1), 31–44.

Yadav, R N, Narain, R, Sarkis, J and Cordeiro J J (2000) The strategic implications of flexibility in manufacturing systems. *International Journal of Agile Management System*, **2**(3), 202–13.

Zhang, Q Y, Vonderembse, M A and Lim, J S (2003) Manufacturing flexibility: defining and analyzing relationships among competence, capability and customer satisfaction. *Journal of Operations Management*, **21**(2), 173–91.

FROM SITUATION ANALYSIS TO DECISION OPTIONS: AN IMPROVED SWOT APPROACH

Weisheng Lu,[1] Roger Flanagan, Koray Pekericli and Carol Jewell

School of Construction Management and Engineering, University of Reading, PO Box 219, Reading, RG6 6AW, UK

Decision making theory suggests that a typical process for making decision comprises sequential steps such as setting objectives, understanding decision situation, generating decision alternatives, evaluating and selecting an optimal option, and so on. This research focuses on the process of generating decision options from a situation analysis. In practice, this process still heavily depends on decision maker's creativity despite the Strengths, Weaknesses, Opportunities, and Threats (SWOT) approach has greatly facilitated it. This research aims to aid the generation of decision options by considering artificial intelligence (AI) as a possible solution. It starts with a critical review of the SWOT as a powerful and popular tool for conducting situation analysis. A weighted matrix is introduced to improve the current SWOT approach. By manipulating the matrix, a heuristic rule is derived. The heuristic rule can be fed into future AI software to generate various decision options.

Keywords: decision making, decision support, situation analysis, SWOT, decision options, artificial intelligence.

INTRODUCTION

Past decades have seen the flourish of different schools of theories about people making decisions. The "rational-analytic" school (e.g. Newell and Simon 1972; Simon 1982) suggested that any decision involves a choice selected from a number of alternatives. The task of rational decision making is to select the alternative that results in the more preferred set of all the possible consequences. The "naturalistic" school (e.g. Klein 1998) emphasizes how people use intuition, action, and adaptation to deal successfully with situations that involve uncertainty and risk. Phillips (1984) proposed a Requisite Model to distinguish itself from any other kind of decision-making model. Compared to different intellectual debates on above theories, A RAND Project AIR FORCE (PAF) survey argues that the frontier of research is seeking to synthesize these different viewpoints and to produce practical suggestions to support decision making that is both analytical and intuitive Having understood various streams of decision making theories, this research has no intention to join their debates.

This research is more about the "rational-analytic" school which assumes that a typical process for making decision comprises sequential steps including setting objectives, understanding decision situation, generating decision options, evaluating and selecting a best/optimal option, and so on (Cooke and Slack 1991). The research focuses on the process from understanding decision situation to the generation of decision options. Understanding decision situation, also called environment analysis,

[1] w.lu@reading.ac.uk

environment scanning, situation analysis, situation assessment or situation audit, is to understand the internal and external environment before any decision is to be made. The philosophy can even be found in Sun Tzu's (BC600) idea : 'Know your enemy, know yourself, and you can fight a hundred battles with no danger of defeat'. Various tools, i.e. five forces model (Porter 1980), resource-based approach (e.g. Wernerfelt 1984; Barney 1991) have been devised to conduct situation analysis. Amongst these tools, the SWOT approach is probably the most powerful and popular one. However, there is not much exciting research advising people how to generate decision options based on a SWOT analysis. Decision options, also called decision alternatives or decision choices, are generated from the situation analysis, from which decision makers can make their choice. Simon (1982) suggested that if there are more choices available for a decision-making problem, the rationality of decision-making will be increased. In actual exercises, the generation of decision options relies heavily on people's creativity; if someone is more creative, he is more capable of generating decision options. It would be helpful if there were a tool that could facilitate this process by simulating human beings. Proctor (1992) expressed a similar interest and made an attempt by developing a computer-aided creativity tool. However, his computer package is very basic, as IT was in its early development at that stage.

The aim of this study is to develop a method for generating decision options based on a SWOT analysis by considering the computer as a possible tool. The study starts from a critical review of the SWOT approach. A weighted matrix is introduced to improve the current SWOT method. By manipulating the matrix, one or more heuristic rules will be derived. The heuristic rules can be interpreted by some AI software packages, and so compiled as a list of decision options. The research enriches the knowledge of the SWOT analysis by envisaging the gap between situation analysis and the generation of decision alternatives. More importantly, it opens a new window by introducing the AI to the decision support exercises.

A CRITICAL REVIEW OF THE SWOT APPROACH

SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. It is a commonly used tool for analysing internal and external environments in order to attain a systematic approach and support for a decision situation (e.g. Kotler 1988; Wheelen and Hunger 1995). It has its origins in the 1960s (Learned *et al*. 1965), and reached its zenith through Weihrich's (1982) milestone work. The principle for using the SWOT analysis is that any decision made should match the environmental threats and opportunities with the organization's weaknesses and especially its strengths. Weihrich (1982) propose a seven-step framework whose core part can be shown in Figure 1. To use the tool, users need to identify and evaluate the opportunities and threats facing an organization, and its strengths and weaknesses. Then users need to develop decision options based on the SWOT analysis. There are four generic decision options, as shown in Figure 1. The S/O options maximize strengths and opportunities; The T/S options maximize strengths and minimize the threats; The S/W options maximize opportunities and minimize weaknesses; The T/W options minimize the weaknesses and threats. Weihrich's (1982) TOWS matrix provides a systematic fashion to connect internal and external factors to stimulate new decision options. Since that, the TOWS matrix has become one of the most powerful and popular tools for supporting decision making.

	Strengths	Weaknesses
Opportunities	S/O Maxi-Maxi	S/W Maxi-Mini
Threats	T/S Mini-Maxi	T/W Mini-Mini

Figure 1: The TOWS Matrix Source (adapted from Weihrich 1982)

Despite the belief that it is somewhat outdated, the SWOT analysis is still one of the most powerful and popular tools for conducting situation analysis. Different from other tools that are doomed to be outdated quickly with the fast development of the fickle management science, the SWOT analysis is still popular because of its inclusivity. It does not exclude other theories that emerged afterwards. As Glaister and Falshaw (1999) suggested, a SWOT analysis may itself encompass a number of different forms of analysis, for example, Porter's five forces model, and resource-based approach, etc. Several other factors have contributed to its popularity: its simplicity; the model can be used without the need for extensive information system; it provides decision makers with a systematic structure for conducting analyses (Piercy 1991).It can be observed that a large number of applications regarding the SWOT approach were reported. Steward (2002) utilized it to determine the implementation of IT/IS projects in construction. Dyson (2004) applied it to the development of strategies for the University of Warwick.

A number of recently reported studies tried to enhance the value of the SWOT approach. Some tried to provide guidelines for where analysts can identify factors of strengths, weaknesses, opportunities and threats. Panagiotou (2003), for example by noticing that "planners are left without indication as to where to search for such (S, W, O, T) variables", suggested a TELESCOPE OBSERVATIONS framework where each letter stands for an aspect for identifying SWOT factors, e.g. T standing for Technological Advancements. The idea itself is not much more novel than the PEST (Political, Economical, Social, and Technical factors framework as suggested earlier by Weihrich (1982). Some other research tried to quantify the SWOT factors by utilizing different quantifying approaches. Notably, there is a hybrid method called A'WOT (Kurttila *et al.* 2000). In this method, the factors by a SWOT analysis are evaluated by using multi-criteria decision support method – AHP (Saaty 1980) in this case. The idea of utilizing the AHP technique within the SWOT framework is to systematically evaluate the SWOT factors and make them commensurable with regard to their intensities (Kurttila *et al.* 2000). In fact, it lacks legitimacy to use the AHP method to compare factors falling in different groups (strengths, weaknesses, opportunities, and weaknesses). Nonetheless, the idea of quantifying SWOT factors is interesting.

There is a limitation of the SWOT analysis that has not been mentioned by previous works. Readers are often excited to see that the identification of SWOT factors is well guided, and the SWOT analysis is well structured. Consequently, a matrix as shown in Figure 2 is derived. However, when it comes to the following step – generating decision options – most writers are "wise after the event" or arbitrary. There are few logical links between the SWOT analysis and the decision options. The only advice readers can get is "to be creative"; users should be creative to generate decision options. Indeed, this process is highly creative (Cooke and Slack 1991), and it seems there is little writers can do with people's creativity. While it is likely that some people are inherently more creative than others (Ribeaux and Poppleton 1978), modern thinking has shifted away from the idea that the situation is one of all-or-nothing, that we are either creative or not, towards the notion that the creative process can be stimulated and improved in the majority of people (Cooke and Slack 1991). It will be very helpful if there is a tool that could stimulate people's creativity and generate more decision options.

	Strengths (S_1, S_2, S_3, …, S_i)	Weaknesses (W_1, W_2, W_3, …, W_j)
Opportunities (O_1, O_2, O_3, …, O_m)	S/O decision options Maxi-Maxi	S/W decision options Maxi-Mini
Threats (T_1, T_2, T_3, …, T_n)	T/S decision options Mini-Maxi	T/W decision options Mini-Mini

Figure 2: A SWOT matrix with factors of strengths, weaknesses, opportunities and threats

AN IMPROVED TOWS MATRIX

Assuming that after a SWOT analysis all the factors are agreed and their relative importance is determined, a weighted TOWS matrix can be derived as shown in Figure 3. The SWOT factors could be identified by brainstorming, or by using the various guidelines such as the PEST, the TELESCOPE FRAMEWORK, or whatever. The relative weightings of the SWOT factors could be derived by engaging the AHP method (Saaty 1980) or the Likert-Scale, and so on.

			Strengths S_1, S_2, S_3, …, S_i	Weaknesses W_1, W_2, W_3, …, W_j
			ω_{s1}, ω_{s2}, ω_{s3},…, ω_{si} (Σ=1)	ω_{w1}, ω_{w2}, ω_{w3},…, ω_{wj} (Σ=1)
Opportunities	O_1, O_2, O_3 … O_m	ω_{o1}, ω_{o2}, ω_{o3}, …, ω_{om} (Σ=1)	S/O decision options Maxi-Maxi	S/W decision options Maxi-Mini
Threats	T_1, T_2, T_3, … T_n	ω_{t1}, ω_{t2}, ω_{t3}, …, ω_{tn} (Σ=1)	T/S decision options Mini-Maxi	T/W decision options Mini-Mini

Figure 3: A weighted TOWS matrix

As the principle of the SWOT approach, any decision option should make use of the opportunities and strengths, or use the opportunities and avoid threats, etc. In reality, not all SWOT factors are matched. Possibly, there may be no relationship between an opportunity and a strength. Weihrich (1982) suggested the use of a '+' to indicate a match between two factors in different category, and an '0' to indicate a weak or non-existent relationship. Consequently, an interaction matrix can be developed. This research will slightly change this mechanism and use a coefficient 'r' to indicate a match, where r=1 means a match and r=0 means a weak or non-existent relationship. Weihrich (1982) also warned that different relationships may have different weights in terms of their potential, so each should be carefully evaluated. In this research, a mechanism has been introduced to indicate different weights of SWOT factors, as shown in Figure 3. By combining these, a weighted interaction matrix can be derived. Use the Opportunity-Strength (O/S) matrix as an example and a weighted interaction matrix can be derived as shown in Figure 4. A similar matrix can be used for analysing the other three generic decision options, e.g. W/O, S/T, and W/T.

			Strengths $S_1, S_2, S_3, \ldots, S_i$					
			ω_{s1}	ω_{s2}	ω_{s3}	…	ω_{si}	(Σ=1)
Opportunities	O_1	ω_{o1}	r_{11}	r_{12}	r_{13}	…	r_{1i}	
	O_2	ω_{o2}	r_{21}	r_{22}	r_{23}	…	r_{2i}	
	O_3	ω_{o3}	r_{31}	r_{32}	r_{33}	…	r_{3i}	
	…	…	…	…	…	…	…	
	O_m	ω_{om} (Σ=1)	r_{m1}	r_{m2}	r_{m3}	…	r_{mi}	

r=0 or 1

Figure 4: A weighted interaction matrix (O/S) between opportunity and strength factors

The weighted O/S interaction matrix can be further expressed as Equation (1).

$$\text{O/S matrix} = \begin{bmatrix} \omega_{o1} * r_{11} * \omega_{s1} & \omega_{o1} * r_{12} * \omega_{s2} & \omega_{o1} * r_{13} * \omega_{s3} & \cdots & \omega_{o1} * r_{1i} * \omega_{si} \\ \omega_{o2} * r_{21} * \omega_{s1} & \omega_{o2} * r_{22} * \omega_{s2} & \omega_{o2} * r_{23} * \omega_{s3} & \cdots & \omega_{o2} * r_{2i} * \omega_{si} \\ \omega_{o3} * r_{31} * \omega_{s1} & \omega_{o3} * r_{32} * \omega_{s2} & \omega_{o3} * r_{33} * \omega_{s3} & \cdots & \omega_{o3} * r_{3i} * \omega_{si} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \omega_{Om} * r_{m1} * \omega_{s1} & \omega_{om} * r_{m2} * \omega_{s2} & \omega_{om} * r_{m3} * \omega_{s3} & \cdots & \omega_{om} * r_{mi} * \omega_{si} \end{bmatrix}_{m \times i} \tag{1}$$

Using a hypothesis case as an example, there are five opportunity and eight strength factors identified. Their weights and match coefficients are all determined. An O/S matrix can be derived as shown in Equation (2).

$$\text{O/S matrix} = \begin{array}{cc} & \\ & \\ O1 & 0.1 \\ O2 & 0.2 \\ O3 & 0.2 \\ O4 & 0.3 \\ O5 & 0.2 \end{array} \begin{array}{c} \begin{array}{cccccccc} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \\ 0.125 & 0.0625 & 0.250 & 0.0625 & 0.125 & 0.250 & 0.0625 & 0.0625 \end{array} \\ \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 \end{bmatrix} \end{array}$$

$$= \begin{array}{c} \\ O1 \\ O2 \\ O3 \\ O4 \\ O5 \end{array} \begin{array}{c} \begin{array}{cccccccc} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \end{array} \\ \begin{bmatrix} 0.0125 & 0 & 0.0250 & 0.00625 & 0 & 0 & 0 & 0 \\ 0.0250 & 0.01265 & 0 & 0.01250 & 0.0250 & 0.0500 & 0.01250 & 0.01250 \\ 0.0250 & 0.01265 & 0.0500 & 0.01250 & 0.0250 & 0.0500 & 0.01250 & 0.01250 \\ 0 & 0.01875 & 0.0750 & 0.01875 & 0.0375 & 0 & 0 & 0 \\ 0.0250 & 0 & 0.0500 & 0 & 0.0250 & 0.0500 & 0.01250 & 0 \end{bmatrix} \end{array}$$

$$= \begin{array}{c} \\ O1 \\ O2 \\ O3 \\ O4 \\ O5 \end{array} \begin{array}{c} \begin{array}{cccccccc} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \end{array} \\ \begin{bmatrix} 1.25 & 0 & 2.50 & 0.625 & 0 & 0 & 0 & 0 \\ 2.50 & 1.265 & 0 & 1.250 & 2.50 & 5.00 & 1.250 & 1.250 \\ 2.50 & 1.265 & 5.00 & 1.250 & 2.50 & 5.00 & 1.250 & 1.250 \\ 0 & 1.875 & 7.50 & 1.875 & 3.75 & 0 & 0 & 0 \\ 2.50 & 0 & 5.00 & 0 & 2.50 & 5.00 & 1.250 & 0 \end{bmatrix} \end{array} / 100 \tag{2}$$

When creating decision options, one may expect that an option can maximize the use of opportunities and strengths. This accords with the principle of the SWOT analysis as discussed previously. Using the above O/S matrix as an example, as shown in Figure 5, if a decision option can cover {O3, S1, S2, S3, S4, S5, S6, S7, S8}, it makes use of the opportunities and strengths to the largest extent. Here the {O3, S1, S2, S3, S4, S5, S6, S7, S8} is called the heuristic rule, as shown in Equation (3).

$$HR_1 = \{O3, S1, S2, S3, S4, S5, S6, S7, S8\} \tag{3}$$

It can be used for stimulating people to generate decision options that cover all these opportunity and strengths.

$$\begin{array}{cc}
 & \begin{array}{cccccccc} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \end{array} \\
\begin{array}{c} O1 \\ O2 \\ O3 \\ O4 \\ O5 \end{array} & \begin{bmatrix}
1.25 & 0 & 2.50 & 0.625 & 0 & 0 & 0 & 0 \\
2.50 & 1.265 & 0 & 1.250 & 2.50 & 5.00 & 1.250 & 1.250 \\
2.50 & 1.265 & 5.00 & 1.250 & 2.50 & 5.00 & 1.250 & 1.250 \\
0 & 1.875 & 7.50 & 1.875 & 3.75 & 0 & 0 & 0 \\
2.50 & 0 & 5.00 & 0 & 2.50 & 5.00 & 1.250 & 0
\end{bmatrix}
\end{array}$$

Figure 5: Heuristic rule for generating decision options

CAN THE COMPUTER HELP?

The previous section introduced an improved TOWS matrix, based on which decision options can be generated to make best use of opportunities and strengths. Human beings can do this but sometimes it is difficult for them to deal with large amounts of information, and to be creative enough. Can a computer help in this case?

Proctor's (1992) work provides a similar insight into this problem. His computer-based approach randomly picked up a keyword from a database, which is carefully developed "to make for interesting ideas". The keyword could indicate a strength, weakness, opportunity, or threat factor that is purely judged by a decision maker. The mechanism will be utilized again to determine the potential options from the SWOT analysis. This study is respected more because of its idea than the success of the IT approach itself.

There are many other exciting AI research findings which could be possibly utilized in this research to generate decision options creatively. Boden (1995) suggested that this kind of creativity could be scientifically understood and facilitated by using AI if the "conceptual space" can be successfully defined. Some computer-based musical composition programs have been developed, i.e. Johnson-Laird's (1989) "Jazz Improvisation". Some AI programs are able to tell stories (e.g. Turner 1992). Although these AI programs are far from mature, one could be optimistic that a program for generating options in this research is possible since the context is relatively simple. As an advantage, the heuristic rule narrowed the "conceptual space". The approaches such as neural network, system dynamics, genetic algorithms, all may provide a basis for this program.

CONCLUSION

It is a logical sequence in a rational decision making process to understand a decision situation firstly, then to generate decision options, and consequently to select a best or optimal option from them. The SWOT analysis is a powerful and popular approach for conducting situation analysis, but there is not much exciting research advising people how to generate decision options based on a SWOT analysis. It is a process of creativity and it is highly desired that there is a tool to aid this creativity process. This study introduced a weighted interaction SWOT matrix to improve the current SWOT approach. This new approach has incorporated the latest advances in SWOT analyses. By calculating the matrix, a heuristic rule for stimulating the formulation of decision options is derived.

The heuristic rule can ideally be interpreted by some AI software packages, and compiled to a list of decision options. Although this research has not developed such an AI package, it seems feasible to develop it after reviewing the related development in creativity AI. Future studies will be conducted to develop such an IT package and validate it in different scenarios.

REFERENCES

Barney, B J (1991), Firm resources and sustained competitive advantage. *Journal of Management*, **17**(1), 99–120.

Boden, M (1995) Creativity and unpredictability. *SEHR*, **4**(2): Constructions of the Mind.

Cooke, S and Slack, N (1991) *Making management decisions*. 2ed. Prentice Hall.

Dyson R G (2004) Strategic development and SWOT analysis at the University of Warwick. *European Journal of Operational Research*, **152**, 631–40.

Glaister, K W and Falshaw J R (1999) Strategic planning: still going strong? *Long Range Planning*, **32**(1), 107–16.

Johnson-Laird, P (1989) Jazz Improvisation: A Theory at the Computational Level, unpublished working- paper, MRC Applied Psychology Unit, Cambridge.

Klein, G (1998) *Sources of Power: How People Make Decisions*. Cambridge MA: The MIT Press.

Kolter, P. (1988) *Marketing Management: Analysis, Planning, Implementation, and Control*. 6ed. Prentice-Hall International Edition.

Kurttila, M, Pesonen, M, Kangas, J and Kajanus, M (2000) Utilising the analytical hierarchy process (AHP) in SWOT analysis—a hybrid method and its application to a forest-certification case. *Forest Policy and Economics*, **1**(1), 41–52.

Learned, E P, Christensen, C R, Andrews, KE and Guth, W D (1965) *Business Policy: Text and Cases*. Homewood:IL: Irwin.

Newell, A and Simon, H A (1972) *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Panagiotou, G (2003) Bringing SWOT into focus. *Business Strategy Review*, **14**(2), 8–10.

Phillips L D (1984) A theory of requisite decision models. *Acta Psychologica*, **56**, 29–48.

Piercy, N (1991) *Marketing-led Strategy Change*. Oxford: Butterworth-Heinemann.

Porter, M E (1980) *Competitive Strategy: Techniques for Analysing Industries and Competitors*. New York: Free Press; London: Collier Macmillan.

Proctor, R A (1992) Selecting an appropriate strategy: a structured creative decision support model. *Marketing and Intelligence Planning*, **10**(11), 21–4.

Ribeaux, P and Poppleton, S (1978) *Psychology and Work*. Macmillan.

Saaty, T L (1980) *The Analytic Hierarchy Process. Planning, Priority Setting, Resource Allocation*. McGraw-Hill.

Simon (1982) *Models of Bounded Rationality. Vol.1&2*. Cambridge, MA: MIT Press.

Stewart, R A, Mohamed S and Daet R (2002) Strategic implementation of IT/IS projects in construction: a case study. *Automation in Construction*, **11**, 681–94.

Turner, S (1992) MINSTREL: A Model of Story-Telling and Creativity. Technical Note UCLA-AI-17-92 (Los Angeles: AI Laboratory, UCLA.

Weihrich, H (1982) The TOWS matrix: a tool for situational analysis. *Long Range Planning*, **15**(2), 54–66.

Wernerfelt, B (1984) Resource-based view of the firm. *Strategic Management Journal*, **5**(2), 171–80.

Wheelen, T L and Hunger, J D (1995) *Strategic Management and Business Policy*. 5ed. Reading, MA: Addison Wesley.

SCENARIO PLANNING FOR CONSTRUCTION COMPANIES

Robby Soetanto,[1] Chris I. Goodier, Simon A. Austin, Andrew R.J. Dainty and Andrew D.F. Price

Department of Civil and Building Engineering, Loughborough University, Leicestershire LE11 3TU, UK

The ability to understand the future holds the key to sustained competitive advantage. The key question is how to embed this ability into the strategic management skill-sets of companies using appropriate tools, techniques and processes, and involving the appropriate stakeholders. Futures methodology literature suggests that scenario planning is a powerful technique for looking at the future that is rarely used in construction. An implementation framework for company scenario planning is proposed derived from relevant parts of the literature and evolved through a series of interactions with industry. The framework emphasizes that the awareness of external factors and industry scenarios, and the extent of stakeholder engagement throughout the process will determine the overall efficacy of scenario planning. Benefits will accrue from having a common understanding of alternative futures by explicitly capturing perceived future events, drivers and pathways in scenario mapping exercises. This should place companies in a better position to navigate their future and deal with potential threats and opportunities.

Keywords: corporate planning, future studies, negotiation, organizational learning, research methods.

INTRODUCTION

The impact of the construction industry on the UK economy is substantial. Construction firms work within a tradition of competitive tendering and small profit margins, but have to be able to respond to fluctuating market demand in order to survive. Construction work often has to be performed in inhospitable or ‘difficult’ environments and the industry has a poor health and safety record (Egan 1998). Construction has been found to be ineffective at planning for the long-term future and lacks forward thinking. A number of reports scrutinizing the performance of the sector (e.g. Egan 1998) have called for the industry to look beyond their next project and prepare themselves better for potential future events and trends.

Strategic planning is a critical management function which could ensure the long-term survival of construction organizations (e.g. Betts and Ofori 1992). Here, ‘strategic planning’ is taken to mean a management function for developing a longer-term plan (beyond the next project), which will shape company characteristics and determine the market in which it is going to operate. Many reasons have been put forward for construction organizations’ lack of effort in strategic planning (Brightman *et al.* 1999), most being inadequate resource capacities, instability of employment and the unpredictability of the construction market. Strategic planning is often the

[1] r.soetanto@lboro.ac.uk

responsibility of senior managers; however, the time they can dedicate to the task is limited as they also have day-to-day operational responsibilities (Burt and van der Heijden 2003). This problem is increased by the prevalence of small construction companies in the sector. Fierce competition and the transient nature of construction employment often results in smaller companies struggling to survive, let alone plan for the long term. Hence, their focus is often just on their current project, as well as winning the next one. If they do plan ahead, then this may have to be aborted because of an emerging need to respond to emerging market demands, hence rendering the whole process of long-term planning less beneficial. In most cases, there is little evidence of a formal process in the formulation of long-term strategies (Edum-Fotwe 1995; Brightman *et al.* 1999). There is thus little capacity for strategic planning in companies in the construction sector and little emphasis on the need for long-term planning as its benefits have not been fully and immediately realized.

Rapid social, economic and technological developments have provided many threats and opportunities for construction companies. The existing modus operandi is perhaps no longer sustainable if they wish to sustain their competitiveness at local, national or global levels. Hence, the need to plan more strategically and better foresee future possibilities is more important than ever before. Enhancing their capacity to foresee futures and plan for them is critical if companies are to prepare and adapt to emerging trends and eventualities that may lie ahead. Scenario planning has recently been heralded as a promising tool to generate possible, probable and preferred longer-term futures (i.e. 20–25 years) for organizations (Hiemstra 2006). This paper reports on a review of literature which provides the basis for developing a process framework for enhancing a construction company's capacity for strategic planning using scenario planning. First, recent evidence of strategic planning practice derived from a survey of senior construction professionals is presented. The role of scenarios in strategic planning is subsequently explained. Causal mapping techniques to capture individual and organizational cognition about the future are described also. A proposed scenario planning activity (the framework) within a firm is then presented. The paper concludes with a discussion regarding the barriers of implementing scenario planning, recommendations for approaches to overcome them, future research activities and potential contribution to knowledge in this area.

STRATEGIC PLANNING IN CONSTRUCTION COMPANIES

Understanding current strategic planning practices within companies is a prerequisite to improving it. Several studies have outlined the generic approaches of strategic planning practices in construction organizations (Brightman *et al.* 1999; Price 2003). A questionnaire survey of senior construction managers in the UK was recently undertaken by the authors to provide information regarding strategic planning practices. Here, the aim is not to provide definitive facts based upon a representative sample, but to provoke further thought and discussion and to enhance the knowledge of current practices in strategic planning.

The first two questions asked the respondent's position within their organization and their experience (i.e. number of years) within the construction industry. The respondents were then asked whether they had been involved in long-term strategic planning and decision making, and if so, how far ahead their strategic planning looked (in terms of number of years). They were asked to identify events that had had an adverse effect on their corporate strategic planning and the extent to which they can possibly avoid or minimize these given the right tools/techniques. The subsequent questions asked about the tools and techniques that the respondents usually use as part of their planning. Here, multiple choices of common tools/techniques were provided, including SWOT (strengths, weaknesses, opportunities and threats) analysis, gap analysis, PESTEL (political, economical, social, technological, environmental and legal) analysis, competitor analysis (i.e. analysing the behaviour and development of similar competitors), as well as no specific technique. Spaces for 'other' answers were also provided.

The final question enquired as to the data and information that the respondents thought most useful for strategic planning, and their effectiveness (in terms of ability to help make the right decisions) in a Likert scale of 1 to 4 where 1 indicates 'poor' and 4 'excellent'. Multiple choices of information were provided, including 'forecasts from internal/external sources', 'statistics (past data)', 'newspapers and magazines', 'personal contacts' and 'intuition and experience'. Again, spaces for 'other' answers were provided. At the end of the questionnaire, the respondents were invited to write additional comments and their contact details, should they wish to get further involved in the research. The questionnaires were distributed during a construction professional institution's annual conference in autumn 2006. Considering the practicality of their distribution, the questionnaires were designed to be fairly simple and took about 15 minutes to complete. Two of the authors attended the conference and personally distributed the questionnaires, as well as leading the delegates through a facilitated process for completing the questionnaires. Forty questionnaires were completed and consequently analysed.

The majority of the respondents were experienced construction professionals who had been in the industry for a significant amount of time (an average of 24 years). Most (85%) declared their involvement in the formulation of long-term strategic planning and decision making. The length of the future plans that they had been involved in varied, but almost half (56%) had a corporate plan for the next five years. Only 18% and 12% indicated that their plans were for 10 and 3 years respectively. Much smaller percentages of them planned for 1, 2 and 20 years. This concurs with Brightman *et al.*'s (1999) assertion that planning horizons are generally limited to between 3 and 5 years. Longer-term plans are often sensitive to changes caused by social, political, economic and technological developments. The majority (70%) indicated that they have personally experienced events that have had an adverse effect on their corporate planning. Most reasons cited were events over which they have no or little control, such as market slumps/recession and change in government policies (political decisions). Current issues such as skills shortage, energy prices and climate change, were also cited, indicating their awareness of the possible impacts that these might have now and in the future.

Most respondents used a combination of several techniques for planning, rather than a single technique. The response showed that 68% used SWOT analysis and 58% used competitor analysis. Gap and PESTEL analyses were used by 32% and 20% respectively. Interestingly, 15% of respondents who were involved in strategic planning activities did not use any techniques at all. A small number of 'other' tools were indicated including 'mind-mapping', 'what-if scenarios' and 'blue-sky thinking/brainstorming'. Anecdotal evidence collected from key construction stakeholders during previous workshops and interviews suggests that 'what-if scenario' techniques and brainstorming sessions are often conducted informally among key decision makers during discussions in company meetings, for example, when they considered alternative options.

Regarding information for developing their strategic planning and its effectiveness, the average responses for ‘forecasts from internal/external sources’, ‘statistics (of past data)’, ‘newspapers and magazines’, ‘personal contacts’, ‘intuition and experience’ were 2.6, 2.5, 2.1, 2.6 and 2.7 respectively. The results highlighted the heavy reliance on intuition and experience in the formulation of strategic plans. It is interesting to note the perceived higher effectiveness of intuition and experience compared with ‘harder’ information such as forecasts and statistics. These findings show a higher degree of subjectivity during the formulation of corporate strategic planning with little participation from lower ranks within the organizational hierarchy. A more formal strategic planning technique which is able to elicit and unify aspirations from staff at various levels might help organizational competitiveness through helping to capture the relatively untapped potential of its workforce.

THE ROLE OF SCENARIOS IN STRATEGIC PLANNING

Thinking about and planning for the future is an integral part of human life. An example of its simplest form is the plans that most people make in the early morning, when they think about their activities for the day, whereas the most complex future planning attempts to look into the long-distance future (e.g. 20–50 years’ time). In everyday life, people naturally construct sequences of future events in their minds when they consider the possible implications of their decisions and actions. In other words, people are unconsciously familiar with building scenarios. So what are scenarios in general, and what do we mean by corporate scenario planning? What are the advantages of using scenarios in comparison to other ‘harder’ futures studies techniques such as forecasting?

A scenario can be simply described as a storyline comprising a range of interconnected and uncertain future events and their possible consequences. Scenarios are often employed for decision-making activities in which some parameters are uncertain or poorly defined, hence scenario-planning techniques’ ability to deal with ‘wicked’ (as opposed to ‘tame’) problems (Rittel and Webber 1973; cf. Rosenhead and Mingers 2001: 5). Earlier futures studies techniques (e.g. based on the extrapolation of current trends) have failed to live up to their expectation as a predictive tool. Instead, scenarios are tools for presenting people perceptions of the alternative environments in which decisions and actions might be played out (Brightman *et al.* 1999). It is not about predicting events or determining the most likely scenario, but is about developing several plausible stories that describe how the environment in which an entity (e.g. an individual or organization) lives or operates, may develop, given certain future events, trends and developments and then exploring possible ‘discontinuities’ and ‘surprises’ (i.e. wild cards) (Hiemstra 2006).

Scenarios provide a framework to develop and evaluate corporate strategies. The utility of scenarios is often analogous to ‘wind-tunnel’ or ‘test-bed’ for corporate strategic decisions. Hiemstra (2006) found that taking a long-range view of about 20 to 25 years is best for corporate planning because this permits people to imagine that things will be different, to make fundamental changes in their organizations, and to seize opportunities that are not given by shorter views (of, for example, three to five years). Some may argue that planning for 20 years is almost impossible, so strategic plans will most likely remain three to five years, which is practical given the speed at which the world is changing today. Thus, scenario planning aims to extend people’s views of the future through thinking of various possibilities, which provides a ‘test-bed’ for strategic plans, allowing them to navigate their future and choose an appropriate direction. This will enhance the organizational capacity for strategic planning and managers' decision-making capabilities (Schwartz 1991; cf. Chermack 2004). However, little is known regarding the conceptual linkage between the decision-making process and scenario planning, in terms of how scenario planning enhances the process and its outcome.

Recently, Chermack (2004) explored the core problems that present themselves in the dynamic decision-making process and outlined the use of scenarios in potentially decreasing the incidence of unexpected decision failure. He identified four main contributors to decision failure, namely: (1) bounded rationality; (2) an emphasis on exogenous variables; (3) 'stickiness' and friction of information and knowledge; and (4) mental models and cognitive maps with their corresponding decision premises or rules. He also explained how the scenario-planning process can reduce the impact of these to improve the effectiveness of the decisions made. Scenario planning makes explicit the mental models of managers for the purposes of analysing, sharing, reconstructing and altering them. Effective decisions should be based upon shared mental models, resulting from the joint decision-making process by key stakeholders (van der Heijden 1996). The main benefit of scenario planning is derived from the process which facilitates organizational learning for the purpose of continuous improvement. The ultimate outcome is not in the scenarios themselves, but within the process as experienced by the participants. Thus, scenario planning is a process of creating an agile, adaptable and prepared organization by 'softening' (and possibly changing) organizational culture to be more receptive towards new thinking (Korte and Chermack 2007). The next step to comprehend this process is understanding what the mental models are and their representations, and how they can be shared, negotiated and altered. This is described in the following section.

MAPPING INDIVIDUAL AND ORGANIZATIONAL COGNITION ABOUT THE FUTURE

Mental models provide a frame of reference for the interpretation of events or phenomena in life (Eden and Ackermann 1998). Mental models govern people's thinking about the future, whether as an individual or as a member of an organization. As noted previously, people are constantly thinking about future events and their interdependencies. Hence, these events and interconnections reside within people's minds and are constructed and interpreted based upon the frame of reference, i.e. mental models. These mental models ultimately govern individuals' behaviours and actions. Changing behaviour requires changing or modifying these mental models.

These mental models become more important when people are working in groups, such as teams, organizations or companies, where coherent and concerted behaviours and actions are essential if a group's objectives are to be achieved. Mental models are the basis for the reasoning of behaviours and actions of individuals within a group. People need to communicate and negotiate intentions and plans, which in turn will be moderated by the other members of the group. This interaction within organizations for developing longer-term plans is called 'strategic conversation' (van der Heijden 1996). To permit this strategic conversation, we need a media of representation, which makes explicit these mental models. Cognitive maps have been advocated by many scholars to objectively exhibit mental models. In general, a cognitive map is simply a graphical representation of a person's thinking, which locates the person in relation to their informational environment (Fiol and Huff 1992; Eden and Ackermann 2001). A number of terms, such as 'mind map', 'brain map' and 'concept map' have sometimes been confused to mean the same thing. Also, the term ‘cognitive map’ was initially meant rather differently and used to represent mental models of the relative locations and attributes of phenomena in spatial environments (Billinghurst and Weghorst 1995; Kitchin and Freundschuh 2000). In this research, we use the term ‘causal map’ which means a map that exhibits people’s perception of a causal network of relationships in a form of nodes and paths (Eden and Ackermann 1998). Nodes contain future events whereas paths (arrows) describe causal relationships between these events, that is, a relationship to show that the occurrence of Event A will lead to the occurrence of Event B or certain actions will lead to particular outcomes. Eden and Ackermann (1998) proposed a way of structuring the map according to a tear-drop/pyramid shape, with the goal/desired outcome at the top, the strategies/key issues, and assertions, supporting facts and options at a lower level. Figure 1 demonstrates an example of a section of a causal map generated from an interview with the regional manager of a civil engineering professional institution as part of data collection exercise to build industry scenarios in specific areas. In this example, the events are arranged not up and down, but left to right so as to allow a sense of time sequence. It addresses the predicted shortage of chartered civil engineers in 2017 due to retirement and decreasing membership. The map was constructed using Decision Explorer™ software, which has been considered the most advanced computer support for cognitive mapping (Tegarden and Sheetz 2003).

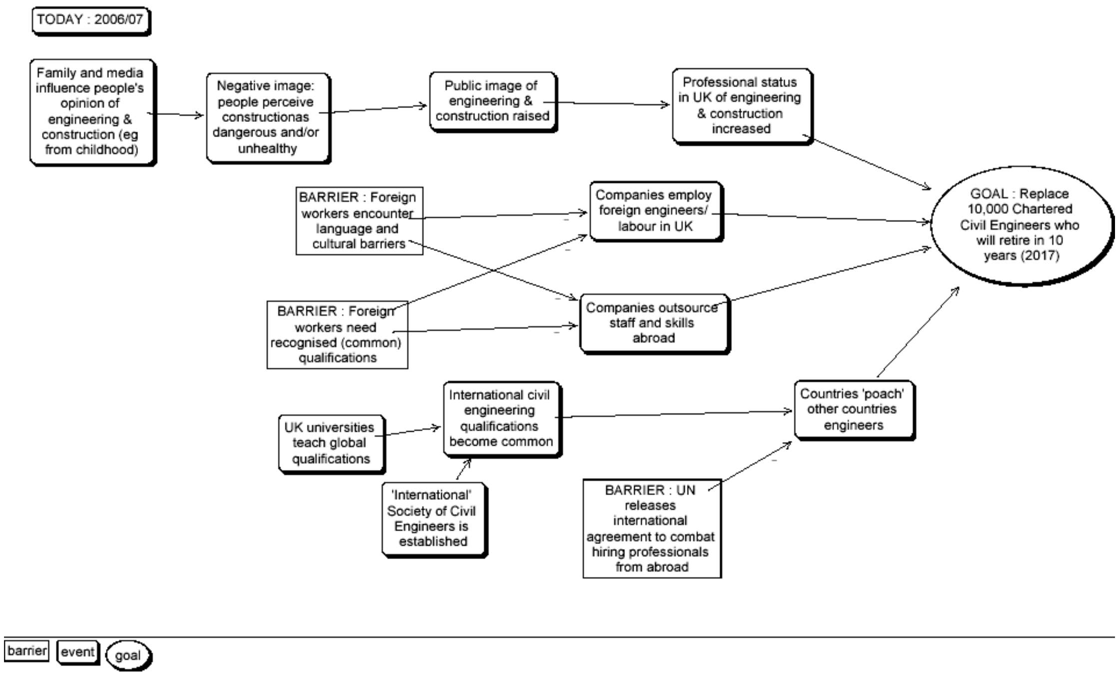


Figure 1: An example of a causal map

The functions of a cognitive map in organizational decision making include: issue structuring (which focuses attention and triggers memory); issue closure (which reveals gaps); and creative problem solving (which highlights key factors and supplies missing information) (Fiol and Huff 1992). Fiol and Huff (1992) identified three components of the cognitive map, namely: identity (to identify key actors, events and processes); categorization (to provide information about the interrelationships of the actors, events and processes); and causal and argument (to provide information about potential interconnections among entities of the importance to the organization through time, i.e. the ‘route’). The identity and categorization components provide the inputs for the causal and argument components. Fiol and Huff (1992) highlighted the significance of managing these interactive components and balancing multiple and often conflicting components and maps of individuals. Individual maps are unlikely to be identical but they may partially overlap.

Corporate strategic decisions are often made through a process of negotiation among stakeholders, in which their idiosyncratic views, interpersonal relationships and politics all come into play. Causal maps can be used for negotiation by reconciliation of goals, the merging of concepts/events and the verification of pathways to the future. Integration of individual maps should maintain a balance between unity and diversity. Lack of unity leads to a dysfunctional map, whereas lack of diversity negates creative production of alternative views of the future, and may also stifle innovation (Fiol and Huff 1992).

Eden and Ackermann (1998, 2001) suggested a way of exposing an individual's causal map to others through a process of 'negotiating' and/or 'merging'. 'Negotiation' occurs when two or more causal maps are going to be integrated by (e.g. organizational or company) stakeholders during a decision-making process. Here, multiple perspectives of an issue facing an organization are invited. 'Negotiation' often involves 'merging', where two concepts are amalgamated into one in the presence of informants and/or interviewers. Theoretically, two or more events can only be merged if they mean exactly the same thing intrinsically. In practice, this is often difficult as even the same word can mean two different things. Merging events would normally involve ascertaining their meanings to the members of a group in a meeting or workshop session. This may lead to three possible outcomes: the events mean exactly the same thing; the events can be merged but need rewording; or the events cannot be merged as the team cannot reach a consensus. The merged maps are referred to as a collective causal map. A number of studies have shown that this process is often problematic mainly because of disagreement on language and its meanings, indicating a lack of shared experiences relevant to a particular domain (Langfield-Smith 1992; Tegarden and Sheetz 2003).

Figure 2 shows how two small parts of two different causal maps can be merged. The maps were produced from two interviews addressing the problem of labour shortage in the construction industry. The goals are slightly different; the first concerns the shortage of engineering professionals, while the second is about labour shortage in general, but focuses more on operatives.

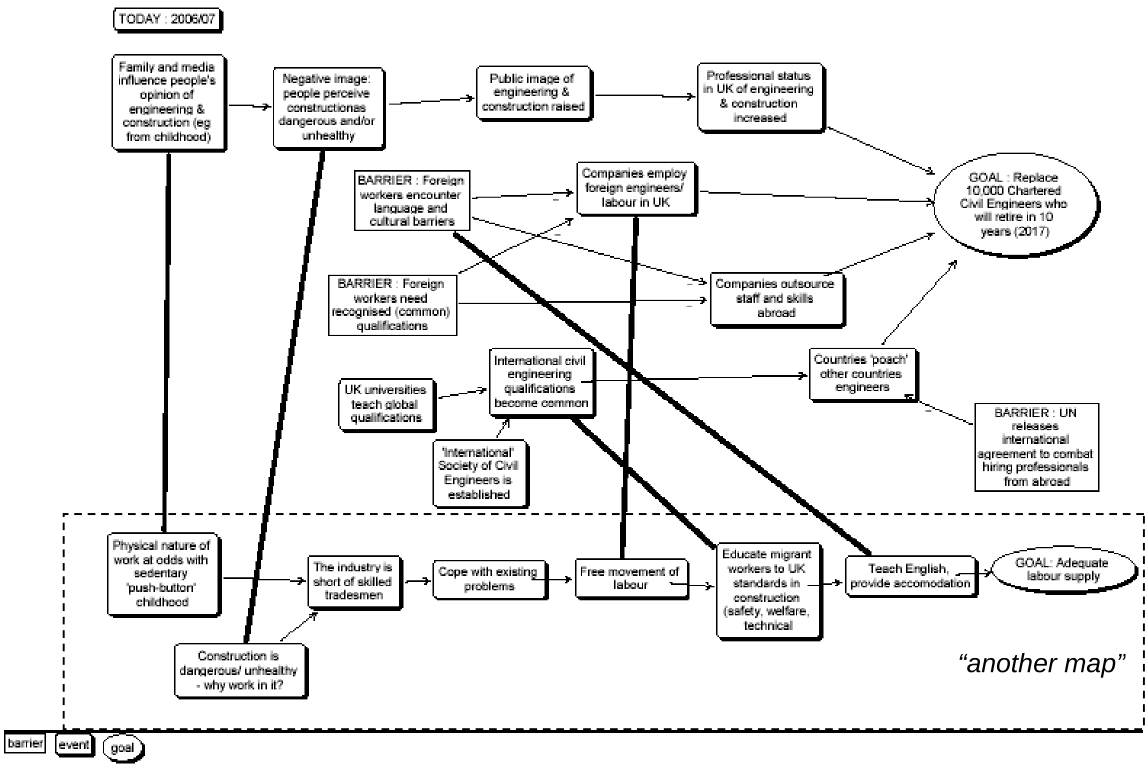
SCENARIO-PLANNING ACTIVITIES: A PROPOSED PROCESS FRAMEWORK

There are as many planning frameworks as there are scenario planners. The process framework presented here is not meant to be prescriptive, but to give generic guidance on how the key principles of scenario planning are implemented in this research. Brightman *et al.* (1999) provided an example of developing scenarios in a construction firm, which is different from this framework, mainly in terms of how employee participation is incorporated in the process and the approach in building the causal maps. The scenario planning is not a 'one-off' but a continuous exercise, linking the development of scenarios and the evaluation of strategic decisions against the scenarios and the implementation of the consequent decisions. This process permits opportunities for reflection and re-perception, as examining possible alternative futures from different angles can clarify key issues and help stakeholders to prepare and develop strategies for achieving their preferred futures (List 2006).

Step 1: Appoint a mapping facilitator and selecting representatives

The first step is to appoint a mapping facilitator, which could be an external consultant or a member of the internal staff (van der Heijden 1996). The person should be a broad thinker with an ability to understand dissimilar issues of importance to different divisions and levels of organizational hierarchy. He/she should possess excellent interpersonal skills to enable them to interact with people from a range of levels. A reasonable knowledge of the organization, in terms of, for example, both ‘hard’ daily business, operation and organizational structure, and ‘softer’ interpersonal relations and organizational politics would also help the facilitator to appreciate issues and concerns as well as the underlying message and implied reasoning. Nevertheless, he/she should be sufficiently detached to maintain an objective view and impartial judgement. This is the balance required between an external consultant and an internal member of staff. An external consultant would bring a new perspective as a view from an ‘outsider’. Nevertheless, internal staff with the above skills may be more advantageous to the business or organization concerned in the long term.

The process begins with selecting representatives from a range of divisions or levels, ensuring those at lower levels are adequately represented. Such representatives would bring benefits in terms of capturing untapped perspectives from different levels, realizing the potential benefits of employee participation and empowerment in solving organization problems. Apart from exploring different views and identifying problems and potential solutions from an operational level, this approach will develop a sense of ownership and commitment to ensure wholehearted support from employees. These representatives will form a ‘scenario team’.



Note: Bold lines indicate linkage between identical events from two different maps

Figure 2: Example of a combined causal map

Step 2: Construct individual causal maps using interviews and brainstorming exercises

A combination of brainstorming and interviews is used to construct individual causal maps via a *Post-it Note* exercise. The aim is to get the most benefit from both techniques while compensating for their different weaknesses. Individual rather than group exercises are preferred in order to capture the individual's pure idiosyncratic views in the first instance – group exercises tend to be influenced by the strong personalities and often result in unproductive disagreements (Scavarda *et al.* 2006). Group exercises can also work against staff at lower levels who feel unable to express their view freely within the presence of their superiors. Facilitator bias in the *Post-it Note* exercise is also much less than that in the interview. Nevertheless, a recorded interview during the session is useful for the benefits of the later analytical stages in the process, particularly for clarifying any issues when merging and negotiating the individual maps.

The individual causal map is constructed on an A1 paper, where a representative can write events on the *Post-it Note* and stick on the paper. *Post-it Notes* ensure flexibility in that they should permit events to be moved freely within the space provided. Cause-and-effect relationships (i.e. arrows) between events can then be drawn – using pencil initially and colour-marker later on. Generally, the map is constructed on a timeline over the next 10–20 years, which does not have to be exact, but is more indicative of the timescale. First, representatives are to identify organizational goal(s), and possibly divisional goal(s), and how both are interlinked (i.e. to build a system of goals (Ackermann *et al.* 2005)). These should be placed on the right-hand side of the A1 paper (i.e. in the future). Then, they write down on the *Post-its* the state of the current situation, together with past events which are relevant predecessors to the present situation, and these are placed on the left-hand side of the paper (i.e. today). The space in between the envisioned 'goal' and the current situation then provides room for external and internal events to take place within that timescale. External events are those related to the changing landscape of political, economical, social, environmental and technological developments, which are outside the influence of the organization. Internal events are possible events happening within the firm, such as changing managing directors or entering new markets, and also possible interventions, such as the recruitment of older workers due to a lack of younger staff (here, to respond to 'ageing population'). The internal events are, to a large extent, controllable by members of the organization. Awareness of industry trends in a broader sense is relevant to this process. Representatives also need to think critically about possible discontinuities and 'wild cards' that may change the 'terrain' on which the firm has to operate. This ensures that the scenarios will embrace as many future uncertainties as possible.

Step 3: Analyse the individual causal maps

This step includes a number of activities, including desk-work, consultation with representatives and other stakeholders, and preparation for the company workshops. The desk-work converts the *Post-it Note* maps into a form suitable for communication, further analysis and manipulation, usually in a computer graphical format with user-friendly software, such as Decision Explorer™. This also involves listing the goals, the current situations, future events, interventions and identifying possible common events to merge. It is also possible at this stage to have a brief consultation with the representatives and stakeholders, to clarify any issues arising, discrepancies or confusing aspects, and develop an awareness of the political and social interaction within the firm. The facilitator(s) should be aware of any possible problems arising from these 'intangible but influential' aspects of the firm. The facilitator should then prepare the outline of activities for the group work (i.e. workshop).

Step 4: Discuss causal maps in a company workshop

An 'organization' is a negotiated and social order, which recognizes that resolution between members to create a new negotiated order requires a social process that explores different perspectives and negotiates an acceptable way forward (Strauss and Schatzman 1963; cf. Eden and Ackermann 2001). Hence, it is imperative that this negotiation process is conducted on an open and cooperative basis, where top level management are receptive towards ideas from those at lower levels in order to obtain social and psychological commitment. Once a sufficient number of individual representatives' causal maps on the same, or similar, theme(s) have been constructed on a one-to-one basis with the facilitator and the analysis completed, a group company workshop can then be held.

The group discussion opens by the presentation of all the individual causal maps. The collective map(s) developed by the facilitator are then presented. The goals and the current situations are reviewed and the representatives interrogated for possible differences and similarities, and they may then be organized within a hierarchy. The next step is to explore possible pathways to achieve the goals, by scrutinizing external events (including discontinuities and wild cards) and the internal interventions necessary to achieve those goals. The merging of events is used to extend the thinking of the participants to alternative ways to achieve a particular outcome. By this time, possible future scenarios for the firm can be identified. It is recommended to identify between two and four (at most six) scenarios to reflect the uncertainties and to ease communication (Brightman *et al.* 2002). These scenarios should contain an interplay of a range of external events that portray possible future environments in which the firm has to operate. The scenarios are also linked with the final goals and the state of the current situation. Any future decisions for the firms should be trialled using the scenarios. In this sense, the resulting outcome is envisaged to resemble the characteristics of both strategic explorative and normative scenarios, which focus not only on internal and external factors, but also on certain objectives and how these could be realized (Börjeson *et al.* 2006).

The outcome of the workshop should be communicated to all staff within the company, whether they were engaged in the process or not, to allow them to reflect on the scenarios and possibly to raise their concern(s). An event inviting them to air their views would provide useful feedback for the scenario team. It is best to consider the scenarios as 'life documents' which are subjected to continual review, update and challenge by organization members. Regular meetings among the scenario team will help this process. The scenario team is analogous to an 'engine of change' for the organization. The whole process will create an awareness of decision-making 'context' for the firm, and improve organizational agility by continuous learning through an established organizational memory.

CONCLUSIONS

The literature review and recent survey revealed little awareness of participating in long-term planning techniques in the UK construction industry. Scenario planning has the potential to enhance the capacity and capability of construction companies to deal with the dynamic and uncertain nature of the sector. Scenario planning will facilitate the creation of adaptive and agile organizations which are better prepared for the future by capturing the creative thinking of its members. Scenario planning is beneficial not only for large organizations, but also for small and medium-sized construction companies, which may have the embedded flexibility that can be honed by the use of scenario planning. The formal application of the technique will improve the company's capacity to learn from past experiences through an established organizational memory. Overall benefits should outweigh the investment made as scenario planning can draw on true potential and commitment through the enhanced empowerment and involvement of the company's staff as well as senior members.

Hence, utilizing scenario planning in construction companies could be viewed as the implementation of innovation in organizations. Scenario planning is also about the changing of organizational culture for the purpose of establishing a 'learning' organization. It is reasonable to expect that some may also resist, or disagree with these proposed changes or their outcomes. Convincing people to embrace these techniques would require the communication of the specific benefits for the company and improving (or convincing) the management's thinking regarding engaging with the future (Burt and van der Heijden 2003). Involving a variety of stakeholders in the process would help to alleviate this obstacle. Importantly, trust between those involved (including the facilitator, scenario team and other stakeholders) has to be nurtured throughout the process. Scenario planning exercises are only deemed successful if they change the minds of people engaged in the process (Wack 1985). These approaches will help to improve the success of scenario planning in construction companies.

FUTURE RESEARCH AND POTENTIAL CONTRIBUTION OF THE WORK

Future work will implement the scenario-planning framework described through a longitudinal study in a number of UK construction companies and consultants. The research will also develop a framework for assessing the efficacy of the approach in terms of the organizational learning experienced and the effectiveness of the process. This will provide a sound basis for the promotion of scenario-planning techniques in the construction industry. Overall, the research endeavours to contribute valuable and much-needed knowledge to this under-developed area in the construction sector.

REFERENCES

Ackermann, F, Eden, C and Brown, I (2005) *The practice of making strategy: a step-by-step guide*. London: Sage Publications Ltd.

Betts, M and Ofori, G (1992) Strategic planning for competitive advantage in construction. *Construction Management and Economics*, **10**(6), 511–32.

Börjeson, L, Höjer, M, Dreborg, K H, Ekvall, T and Finnveden, G (2006) Scenario types and techniques: towards a user's guide. *Futures*, **38**, 723–39.

Brightman, J R, Eden, C, van der Heijden, K and Langford, D A (1999) The development of the construction alternative futures explorer. *Automation in Construction*, **8**, 613–23.

Brightman, J R, Eden, C, van der Heijden, K and Langford, D A (2002) *CAFÉ user's guide*, version 1.2. Banxia Software Ltd, available at www.banxia.com/dexplore/cafe.html.

Burt, G and van der Heijden, K (2003) First steps: towards purposeful activities in scenario thinking and future studies. *Futures*, **35**, 1011–26.

Chermack, T J (2004) Improving decision-making with scenario planning. *Futures*, **36**, 295–309.

Eden, C and Ackermann, F (1998) *Making strategy: the journey of strategic management*. London: Sage Publications.

Eden, C and Ackermann, F (2001) Group decision and negotiation in strategy making. *Group Decision and Negotiation*, **10**, 119–40.

Eden, C and Ackermann, F (2001) SODA – the principles. *In*: J Rosenhead and J Mingers (Eds.) *Rational analysis for a problematic world revisited*. 2ed. Chichester: John Wiley & Sons Ltd.

Edum-Fotwe, F (1995) *A framework for improving the strategic management of construction contractors*, Unpublished PhD Thesis, Loughborough University, UK.

Egan, J (1998) *Rethinking construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions. London: HMSO.

Fiol, C M and Huff, A S (1992) Maps for managers: where are we? Where do we go from here? *Journal of Management Studies*, **29**(3), 267–85.

Hiemstra, G (2006) *Turning the future into revenue: what businesses and individuals need to know to shape their futures*. New Jersey: John Wiley & Sons, Inc.

Kitchin, R and Freundschuh, S (Eds.) (2000) *Cognitive mapping: past, present and future*. London: Routledge.

Korte, R F and Chermack, T J (2007, forthcoming) Changing organizational culture with scenario planning. *Future*, doi:10.1016/j.futures.2006.11.001.

Langfield-Smith, K (1992) Exploring the need for a shared cognitive map. *Journal of Management Studies*, **29**(3), 349–68.

List, D (2006) Action research cycles for multiple futures perspectives. *Futures*, **38**, 673–84.

Price, A D F (2003) The strategy process within large construction organisations. *Engineering, Construction and Architectural Management*, **10**(4), 283–96.

Rittel, H W J and Webber, M M (1973) Dilemmas in a general theory of planning. *Policy Science*, **4**, 155–69.

Rosenhead, J and Mingers, J (2001) A new paradigm of analysis. *In*: J Rosenhead and J Mingers (Eds.) *Rational analysis for a problematic world revisited*. 2ed. Chichester: John Wiley & Sons Ltd.

Scavarda, A J, Bouzdine-Chameeva, T, Goldstein, S M, Hays, J M and Hill, A V (2006) A methodology for constructing collective causal maps. *Decision Sciences*, **37**(2), 263–83.

Schwartz, P (1991) *The art of long view*. New York: Doubleday.

Strauss, A and Schatzman, L (1963) The hospital and its negotiated order. *In:* E Friedson (Ed.) *The hospital in modern society*. New York: Macmillan.

Van der Heijden, K (1996) *Scenarios: the art of strategic conversation*. Chichester: John Wiley & Sons.

Schwartz, P (1991) *The art of long view*. New York: Doubleday.

Strauss, A and Schatzman, L (1963) The hospital and its negotiated order. *In:* E Friedson (Ed.) *The hospital in modern society*. New York: Macmillan.

Van der Heijden, K (1996) *Scenarios: the art of strategic conversation*. Chichester: John Wiley & Sons.

Wack, P (1985) Scenarios: shooting the rapids. *Harvard Business Review*, **63**(6), 139–50.

A CRITICAL ASSESSMENT OF THE VIABILITY OF COST BENEFIT ANALYSIS IN THE MANAGEMENT OF CONSTRUCTION HEALTH AND SAFETY

Elias Ikpe[1], Keith Potts, David Proverbs and David Oloke

School of Engineering and the Built Environment, University of Wolverhampton, PO Box 219, Wolverhampton, WV1 1SB, UK

Health and safety issues are major concerns in the UK construction industry. Evidence suggests that research studies on construction health and safety management issues have yet to lead to a significant reduction in the number of accidents. To tackle the causes of days lost through accidents and to improve production in the construction industry, the industry needs to understand the cost–benefit analysis (CBA) of effective health and safety management. The introduction of CBA will decrease work-related injuries and help to achieve a higher rate of productivity. A review of the viability of cost–benefit analysis and its relevance for health and safety management in the construction industry is presented. This is part of a wider study to improve the management of health and safety and to propose a way forward for safer and healthier construction sites. The willingness to pay (WTP) approach is identified as the most suitable approach as it is more consistent, computationally easier and is not based on assumption. This method also has the potential to contribute to a reduction in costs, deaths and injuries in the construction industry. The results of this investigation will form part of an ongoing study of cost–benefit analysis for construction health and safety management.

Keywords: construction health and safety management, cost–benefit analysis, viability.

INTRODUCTION

According to the Health and Safety Executive (HSE 2006) each year in the UK there are over 1 million injuries at work and 2.3 million cases of ill health experienced by workers. In addition around 40 million working days are lost to business and over 25 000 individuals are forced to give up work because of injury or ill health. These cost British employers an estimated £3.3–£6.5 billion each year of which £910–£3710 million results from accidental damage to property and equipment. Unfortunately, most organizations do not know what accidents and ill health really cost them in time and money.

Accidents in the construction industry continue to occur at a high rate despite different measures adopted by HSE to reduce the rate of accidents. There is, however, little research work that deals with the cost–benefit relationship of health and measures on construction sites. This high rate of accidents in the construction industry indicates a potential benefit from the introduction of a cost–benefit analysis (CBA) approach prior to initiating the construction project. A literature review of

[1] elias.ikpe@wlv.ac.uk

CBA and its potential for helping improve health and safety management in the construction industry is presented. The industry needs a guide such as CBA for effective accident reduction because the existing regulations set by the UK government on health and safety issues have not yet reduced accidents in the construction industry to an acceptable level.

The aim of the paper is to critically assess the viability of the use of CBA and how its use will lead to improvement in the management of health and safety in the UK construction industry. The objective is to identify an appropriate method of measuring benefits of health and safety management in the construction industry. The process described in this paper would be appropriate to guide contractors and decision makers on how costs and benefits of health and safety could be estimated and measured and also to encourage them to invest in health and safety.

BACKGROUND

Carcoba (2004) defines cost–benefit analysis (CBA) as a technique designed to determine the feasibility of a project by quantifying its costs and benefits. CBA is a practical way of assessing the desirability of projects where it is important to take a long view and a wide view (Barker and Button 1995). CBA helps policy and decision makers better understand the role they can play in helping them fulfil their decision-making responsibilities (Lagas 1999). It provides a means of comparing complex projects, even when benefits and costs occur during different time periods. CBA also provides a means for systematically comparing the value of outcomes with the value of resources achieving the outcomes required (Watkins 2006). It could be regarded as a systematic means to enumerate all benefits and all costs (Marsh and Flanang 2000).

CBA aids the decision-making process by giving monetary values to the costs and benefits so that a comparison can be made to choose the best option. It involves estimating the equivalent money value of the benefits and costs to the community of projects to establish whether they are worthwhile (Watkins 2006). Thus cost–benefit analysis could be of value to help improve health and safety management in the construction industry.

INTERNATIONAL PRACTICE OF CBA

The practice of CBA differs between countries and even between sectors within countries. Some of the differences may include the types of impacts that are included as costs and benefits within the appraisals, the extent to which impacts are expressed in discounting rates in monetary terms and different discounting rates between countries (Arrow *et al*. 1996). CBA has been widely used in Japan, Sweden and the USA to improve their decision making and the performance of organizations. A brief review of these international experiences now follows.

USA

The motivating force behind CBA in the USA was a desire to allay conflict and reach an agreement. Most of the early development work on CBA as a discipline was the result of problems faced by the US Army Corps of Engineers in deciding how and where to build bridges in supporting combat operations. Before the creation of the corps, evaluations of public investments were almost completely ad hoc (Arrow *et al*. 1996). The prestige of the corps along with its increasing quantification of project cost and benefit was used by Congress to simplify its decision making and avoid the wildly uneconomic projects produced by logrolling (Bjornstad 2006). CBA is often referred to in the USA as benefit–cost analysis (BCA). BCA is now a well-known established discipline in the USA. It is a technique used for assessing the desirability of government projects and policies. It considers alternative policies and identifies the one that yields the greatest gain to society. It provides much useful information to the political process. It has been widely used in the design of environmental policies and to help resolve disputes under the US legal system.

According to Arrow *et al*. (1996) in the USA, the use of CBA is based on at least three alternatives for consideration and the choice of alternative is based on the most effective cost within the context of budgetary and political considerations. In choosing the alternative, the analyst considers at least three alternative means of achieving programme objectives. This will provide them a comparative baseline. The analyses of CBA are two types (Arrow *et al*. 1996):

- BCA which is defined as a systematic quantitative method of assessing costs and benefits of competing alternative approaches.
- A cost effective analysis (CEA) is a simplified BCA which can be done when either the benefits or the costs are the same for all the alternatives.

The best alternative is either the one with benefits or the one with lowest costs.

CBA is believed to be very helpful in government rule making and other regulatory efforts. As part of the 1998 Budget Message to Congress and in fulfilment of the Government Performance and Results Acts, the report demonstrated the challenges to be overcome if government is to inform decision making using CBA (Bjornstad 2006). In 1994, President Clinton issued an executive order confirming the government's commitment to CBA and highlighting the bipartisan support for CBA in federal regulatory decision making. At the highest levels, the US government maintains that CBA is indeed helpful to identify the potentially good versus the potentially bad of 'significant regulatory action' (Ackerman 2004 as cited in Bjornstad 2006). It is regarded as a cost effective and improved method. It helps in making difficult decisions and also in making the best choice of the alternatives.

According to Lagas (1999), the US last four presidents, divided equally by party, have required that CBA of regulatory rule making be conducted in their Office of Management and Budget (OMB). The Clinton administration from 1992 until 2001 extended the role of CBA through its support of the Government Performance and Results Act and through its interpretation of its role under this Act; the Clinton administration placed greater emphasis on the quantitative measurement of costs and benefits as part of the regulatory process. In addition, CBA has been used effectively to preserve environment or health in the USA through the Environmental Protection Agency. The Environmental Protection Agencies have committed to develop agency-wide guidance for CBA that parallels its highly successful risk management guidance (Bjornstad 2006). Furthermore, the Flood Control Act of 1936 provided what could be interpreted as the first legislative mandate to use CBA in the USA by declaring that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, if the benefits to whomsoever they may accrue are in excess of estimated costs.

Sweden

In Sweden, there has been significant interest in the subject for over 20 years (Johanson and Mabon 1998 as cited in Johanson and Johren 2006). Significantly, the subject of cost–benefit analysis (CBA) has consistently worked itself up the occupational safety and health (OSH) agenda in the last few decades.

As an example, a Swedish forestry contractor experienced high levels of work-related injuries over a period of a decade and in 2004 carried out a CBA on investments to try and decrease these injury levels (Johanson and Johren 2006). This was introduced to decrease work-related injuries and to achieve a higher rate of productivity. The successful outcome has led to CBA now playing an important part in the contractor's decision-making processes at work.

In Sweden, the costs of sick leave are less than 1% of personnel costs (Johanson and Johren 2006). This was achieved because of the introduction of the use of CBA. It was revealed that organizations that invest more in training have lower costs for sick leave. Furthermore, the costs of safety have decreased in recent years; this could be seen as the basic argument for the use of CBA in health and safety management. The costs of injuries include the loss of productivity and disruption caused (Joyce 2001). The use of CBA will improve production in the construction industry and also benefits workers, employers and society.

Japan

The business environment surrounding Japanese industries has been very strict for the past few years because of long stagnation forcing executives to adopt effective management to make the most of limited resources (Japan Industrial Safety and Health Association 2000). This prompted the government of Japan to introduce CBA especially in developing new safety measures. The costs were grouped into two as costs related to safety (expenses invested to prevent accidents) and costs caused by accidents. When these costs occur, the government shoulders part of the responsibilities by offering some compensation under the Labour Law but sometimes the organization bears the cost when the company has violated its obligation to ensure safety.

The implementation of health and safety management in Japan led to an improvement of production and productivity, improvement of work motivation and personal relationships in the worksite, and improvement of the corporate image of the organization. The introduction of CBA in Japanese industrial safety has reduced the rate of accidents. If the UK construction industry were to adopt such Japanese and Swedish practices by introducing CBA procedures, accident rates might begin to fall to an acceptable level.

THE USE OF CBA

CBA could be used to examine or investigate the social and economic viability of health and safety management in the construction industry at the planning and operational stages (Ikpe *et al*. 2006). The decision makers can obtain useful information on the positive and negative effects to know if the benefits exceed the costs. The construction industry faces numerous constraints, which could hamper the effective management of health and safety. The main source of constraint to implement health and safety management is cost (Kheni *et al*. 2005). This constraint has a negative impact on the management of health and safety which can result in poor health and safety of construction sites and may also manifest in the form of a poor quality of service. The need for effective health and safety management must be addressed to deliver safe and good projects (Carpenter 2006). The improvement of construction health and safety management will reduce accident costs and contribute significantly to the well being of workers, employers and society (Shutt 1995).

Accidents have negative effects on the construction industry and give the industry a bad reputation (Ikpe *et al*. 2007). According to the HSE (2006) losing skilled workers even for a few days can have a bigger effect than direct financial costs might suggest. Evidence from a literature review suggests that improving health and safety management at the worksite can generate significant savings. One of the most obvious costs as identified by HSE is in respect of a person taking time away from work. Mishan (1982) identified benefits to be gained to include the time saved and the benefits of increased comfort and convenience. A well-managed CBA approach to health and safety management might lead to significant cost savings and improvements in safety performance (Ikpe *et al*. 2006).

CBA is a key input for the investment review that should take place before a new project proceeds to the acquisition or development phase (Snell 1997). Most studies concerned with the effects of health promotion programmes have tended to ignore the economic consequences. Conrad (1987 as cited in Johanson and Johren 2006) proposes that one reason for this may be that the effects of health programmes are mostly subjective, individual results. Although this is certainly true, such factors as changes in sickness rates and productivity, among others, could be measurable in monetary terms. However, the main economic effects of health and safety are probably changes in productivity. The direct benefits from improved safety in construction are the reduction of accidents and financial losses due to accidents and ill health. Such cost reduction therefore benefits society as a whole and not merely the workers and employers. According to Gary (1969) accident reduction is clearly an economic benefit.

CBA MEASUREMENT

In order to measure economic benefits and costs of accidents, they must be expressed in monetary terms. Where all benefits and costs can be expressed in monetary units, CBA provides decision makers with a clear indication of the most efficient alternative, that is, the alternative that generates the largest net benefits to society (Georgi 1993). CBA focuses on the future, so decisions have to be based on the expected costs and benefits of proposed alternatives (Seeley 1996). While past experience may be relevant in helping to estimate the value of the future benefits and costs, CBA should be explicit about the underlying assumptions used to arrive at estimates of future benefits (Lagas 1999).

For the purpose of estimating, the cost of injuries is more difficult to measure as is the cost of medical treatment for the injured person. In the case of measuring a fatality, problems may arise of putting a value on human life. However, it can be expressed in monetary terms. The measurement of costs and benefits helps to solve the most important question of economic practice, which also determines the effectiveness of social labour. The effectiveness of labour is usually evaluated in terms of productivity (Novozhilov 1997).

Methods used in CBA measurement

According to Lagas (1996) the use of incorrect methods of CBA orients economic activity towards excessive expenditures and the pursuit of imaginary results, and gives rise to contradictions between economic accountability and the plan. Some methodologies used in CBA include the following.

The *net present value* (NPV) method considers all future cost–benefit flows (Bjornstad 2006). This method yields one value that is easily interpreted. If the value is positive, the project yields benefits that exceed its costs. If the value is negative, costs exceed benefits. The present value is calculated using the following formula by (Bjornstad 2006) as:

$$PV = FV\left(\frac{1}{1+r}\right)t$$

where *PV* = present value, *FV* = future value and r = discounting rate t discounting periods.

Another method is the *willingness to pay* (WTP). The WTP for improved health is a function of the productivity improvement (Morris and Willcocks 1996) and is expressed as

$$\text{WTP} = \text{price paid} + \text{consumer surplus}$$

The WTP reflects the amount that someone who does not have a good would be willing to pay to buy it. It represents the maximum amount of money that individual is willing to pay in exchange for an improvement in circumstances or consumer surplus brought about by a policy (Layard and Glaister 1994). It is based on the assumption that it is reasonable for people to be willing to pay to avoid accidents and to obtain improved conditions (Kopp *et al*. 1997). It is the maximum amount of money one would give up to buy some good or service, or would pay to avoid harm (Pearce 1983). In order to tackle the causes of days lost through accidents and to improve production in the construction industry, the willingness to pay approach could be used to acquire the benefits or to avoid the costs. The worth or value of a thing to a person is determined simply by what a person is willing to pay for it (Mishan 1982).

The *internal rate of return* (IRR) is another method for determining value that does not depend on the determination of a discount rate and that expresses value in terms of a percentage. IRR is based on the assumption that the cost–benefit flows are reinvested at the internal rate of return. If projects like construction health and safety are to be examined, IRR may yield results that are inconsistent with a ranking based on the NPV method. The method requires the compounding of all positive cost–benefit flows to the last period of the project life period, at a given rate. The formula for compounding values forward is expressed as:

$$\text{FV} = \text{PV}(1+r)T - t$$

where *t* is the compounding periods and *T* is the final period.

The *discounting rate* method is the rate by which benefits that accrue in some future time period must be adjusted so that they can be compared with values in the present. In principle, this rate is the rate that equilibrates the demand for savings by investors and the supply of savings from savers who refrain from spending all their income on current consumption (Brent 2003). This method is not as consistent as net present value or willingness to pay as it is based on assumptions.

The choice facing the decision maker is which of these many methods to apply in cost–benefit analysis for health and safety management. If the discounted present value method is adopted, the question for the appropriate rate of discount arises. In such exceptional cases there would then seem to be no more justification for discounting such future benefits to be enjoyed by workers in the construction industry.

Although NPV represents an effective method to be adopted as it is both consistent and acceptable, CBA focuses only on either the mean or mode of the NPV or IRR and it can be argued that this on its own does not provide enough information for a valid decision where projects may be uncertain (Barker and Button 1995). However, the WTP approach is identified as the most suitable approach as it is more consistent, computationally easier and is not based on assumptions. This method also has the potential to contribute to a reduction in costs, deaths and injuries in the construction industry and may be more appropriate to compute the benefits of health and safety on the basis of individual willingness to pay. Thus in applying to health and safety management policy, it will seek to obtain the amount that contractors will be willing to pay to improve health and safety management in the construction industry.

WTP has not been used as a measure of benefits in economic valuations of health and safety in the construction industry as in other fields. It can be used to find out benefits to any individual of non-marketed benefits such as clean air, peace and quiet (Pearce 1983). Pearce (1983) gave an example of this as the willingness to agree to work in a hazardous environment where there is great risk of death and risk means cost. Another advantage of WTP is that it can be used to provide individuals with an incentive to realize their maximum benefits. WTP as measure of benefits can estimate the benefits in monetary terms as individual willingness to pay. The disadvantage of WTP is that it cannot be used to measure CBA if the outcome is uncertain. Another disadvantage is that the WTP estimate is usually based on hypothetical questions and the correlation with actual behaviour is generally unknown. It can increase the impact on decision makers. The justification for adopting these methods of measurement (WTP) is that they correspond with the psychological sense of gains and losses because benefit and cost are measured in terms of gains and losses.

CONCLUSION

The potential of using CBA for improving the management of construction health and safety in the construction industry has been presented. If undertaken in the construction industry, it will allow decision makers to identify potential improvements on health and safety management. Cost–benefit analysis has not been as widely practised in the construction industry as in others. The introduction of CBA will decrease work-related injuries and help to achieve a higher rate of productivity. CBA is capable of being used effectively for improving health and safety management in the construction industry. If the risk of death or injury could be significantly reduced in the construction industry by applying cost–benefit analysis then there would little to doubt why it should not be implemented.

The proper method of measuring benefits is willingness to pay (WTP). The WTP approach is more consistent, computationally easier, is not based on assumptions and has the potential to measure benefits of improving health and safety management. This method also has the potential to contribute to a reduction in costs, deaths and injuries in the construction industry. A well-managed CBA approach to health and safety management might lead to significant cost savings and improvements in safety performance. This information could be a useful guide for contractors and decision makers to address health and safety issues on construction sites.

REFERENCES

Arrow, K, Cropper, M L, Eads, G C, Hahn, R W, Lave, L B, Noll, R B, Portney, P R, Russell, M, Schmalensee, R, Smith, V K and Stavins, R N (1996) *Benefit–cost analysis in environmental, health and safety regulations: a statement of principles*. Washington, DC: American Enterprises Institute.

Barker, P and Button, K (1995) *Case studies in cost-benefit analysis*. London: Heinemann Ltd.

Bjornstad, D (2006) *Cost benefit analysis*, available at http://www.ncedr.org/tools/other/tools/costbenefit/lead.htm (accessed 18 August 2006).

Brent, R J (2003) *Cost–benefit analysis and health care evaluations*. Cheltenham: Edward Elgar Publishing Ltd.

Carcoba, A (2004) Whose costs? Who benefits. *Journal of European Agency for Safety and Health*, available at http://www.agency.osha.eu.int/publications/magazine/1/en/index_5.htm (accessed 13 March 2006).

Carpenter, J (2006) *Developing guidelines for the selection of designers and contractors under the Construction (Design and Management) Regulations 1994*. Research Report 422 for Health and Safety Executive.

Gary, F (1969) *Transport investment and economic development*. Washington, DC: The Brookings Institution.

Georgi, H (1993) *Cost benefit analysis and public investment in transport: a survey*. London: R J Acford Ltd.

HSE (2006) *The costs of accidents and ill-health at work*, available at http://www.hse.gov.uk/costs/costs_overview/costs_overview.asp (accessed 7 September 2006).

Ikpe, E, Potts, K F, Proverbs, D and Oloke, D (2006) The management of construction health and safety: investigating the cost-benefit. *In*: D Boyd (Ed.) *Proceedings: 22nd Annual ARCOM Conference*, 4–6 September 2006, Birmingham. Vol. 1, 295–304.

Ikpe, E, Potts, K F, Proverbs, D and Oloke, D (2007) Improving health and safety management in the construction industry: a critical review of prevention, control and evaluation measures. *In*: W Fadare and A Adesanya (Eds.) *Proceedings: Towards a sustainable built and natural environment*, Obafemi Awolowo University Ile-Ife, Nigeria, 126–32.

Iverson, D (2002) *Top ten reasons why cost benefit fails in public choice settings*, available at http://forestrpolicy.typepad.com/10_reasons_cba_fails.html (accessed 13 March 2006).

Japan Industrial Safety and Health Association (2000) *Cost–benefit analysis of safety measures*, available at http://66.249.93.104/searchq=cache:Rj3Y7VATKAwj:www.jisha (accessed 5 May 2006).

Johanson, U and Johren, A (2006) The practice of CBA at company level in Sweden. *European Agency for Safety and Health Magazine*, 1, available at http://www.agency.osha.eu.int/pu/magazine/1/index-13.htm (accessed 7 September 2006).

Joyce, R (2001) *The Construction (Design and Management) Regulations 1994 explained*. 2ed. London: Thomas Telford Ltd.

Kheni, N A, Dainty, R J A and Gibbs, G F (2005) Health and safety management practices of small sub contractor. *In*: F Khosrowshahi (Ed.) *Proceedings 21st Annual ARCOM Conference*, 7–9 September 2005, London. Vol. 1, 105–14.

Kopp, J R, Krupnick, J A and Toman, M. (1997) Cost–benefit analysis and regulatory reform: an assessment of the science and the art. Discussion Paper 97-19, Washington, DC.

Lagas (1999) *Cost–benefit analysis guide for NIH IT projects*, available at http://irm.cit.nih.gov/itmra/changuide.html (accessed 18 August 2006).

Marsh, L and Flanagan, R (2000) Measuring the costs and benefits of information technology in construction. *Journal of Architectural Management*, **7**(4), 423–35.

Mishan, E J (1982) *Cost–benefit analysis: an informal introduction*. 3ed. London: George Allen & Unwin Publisher Ltd.

Morris, S and Willcocks, G (1996) *Preventing accidents and illness at work: health and safety in practice.* London: Pitman Ltd.

Novozhilov, V (1997) *Problems of cost benefit analysis in optimal planning*. New York: Arts and Science Press Ltd.

Seeley, H I (1996) *Building economics: appraisal and control of building design cost and efficiency*. 4ed. Basingstoke: Macmillan Ltd.

Shutt, R C (1995) *Economics for the construction industry*. 3ed. Essex: Longman Ltd.

Snell, M (1997) *Cost–benefit analysis for engineers and planners*. London: Thomas Telford Ltd.

Watkins, T (2006) *An introduction to cost–benefit analysis*, available at http://www2.sjsu.edu/ faculty/Watkins/cba.htm (accessed 15 July 2006).

FUZZY SETS METHOD APPROACH FOR VENDOR SELECTION IN GREECE

Odysseus G. Manoliadis[1] and Ioannis Tsolas[2]

[1]*School of Technological Application, Technological Education Institute of Kozani, Kozani, Greece*
[2]*School of Applied Mathematics and Physics, National Technical University of Athens, 9 Iroon Polytechniou Str, Zografou Campus, Athens, Greece*

In Greece, as in many other countries, the current system of the most advantageous tender selection still causes concerns in terms of its potential crises, such as the problematic quality inappropriate evaluating methods, insufficient reviews on the contract fulfilment result and feedback. This paper presents a systematic procedure based on fuzzy sets theory aiming to evaluate the capability of grouped vendor suppliers to deliver the project as per the owner's requirements. The theory of fuzzy sets is applied to the above problem in order to estimate criteria weights for this case. The criteria examined were economical criteria, technological criteria, item delivery criteria and service criteria. In order to face problems concerning the applicability of the problem in practical cases deriving from the Greek Legislative Law, a methodology is tailored to face categorized cases after clustering historical data. A case study from a procurement case in Greece is following. The results strengthen the opinion that the fuzzy sets method is a powerful and appropriate technique for deriving objective solutions in categorization of procurement cases and is a rather subjective area such as the procurement system for vendor selection. Conclusively, the proposed methodology can be used as a tool to adopt the quantitative methods properly combining the different opinions of the evaluation committee members in order to represent the overall evaluation.

Keywords: contractor selection, decision analysis, fuzzy logic, tendering.

INTRODUCTION

Selecting the tender is an important step during government procurement processes. It directly determines whether an entity is capable of attaining high-quality products within fixed budget and time allotment. Lately, increasing importance of tender selection decisions is forcing organizations to rethink their evaluation strategies and hence the selection of suppliers has received considerable attention in the literature (Nydick and Hill 1992; Verma and Pullman 1998; De Boer 1998; Handfield *et al*. 2002).

Vendor selection in Greece was first done based on tender price alone. Greek government procurement had predominantly awarded the contract to the lowest tender. This was quite risky and sometimes led to the failure of the project in terms of time delay and poor quality standards. It was profound the necessity to inspect and improve on the current system of most advantageous tendering selection. Ten years ago the valuation of vendors was changed based upon EU guidelines (i.e. 72/62/EC, 93/36/EC and 80/67/EC) and is merely a multiple criteria decision making (MCMD) procedure. The criteria used were economic and technical and the procedure was

[1] omano@tee.gr

becoming more popular. The first attempts to evaluate these criteria were to sum up their values though lately ranges of weights were proposed by Legislative Law (i.e. 394/1996). However, the current system of the most advantageous tender still causes concerns in terms of its potential crises, such as the problematic quality inappropriate evaluating methods, insufficient reviews on the contract fulfilment result and feedback.

Therefore, how to adopt the quantitative methods properly combining the different opinions of the evaluation committee members in order to represent the overall evaluation of the committee as well as to improve the major concern of the most advantageous tender system is worthy of research attention.

The objective of this paper is to present a systematic procedure based on fuzzy sets theory to evaluate the capability of grouped vendor suppliers to deliver the project as per the owner's requirements. The theory of fuzzy sets is applied to the above problem in order to estimate criteria weights for this case and is compared to the existing procedure in terms of a multi criteria decision making technique.

In the following paragraphs, first there is a briefing on determining the tender that ranks first as regulated by the existing law in Greece is discussed. The literature review on evaluating the selection methods of the most advantageous tender follows. Then, the theory of fuzzy sets aiming to improve the evaluation procedure in categorized case studies is proposed. Finally, a case study is utilized to validate the advantages of the recommended procedure improvement.

TENDERING AS REGULATED BY THE GREEK LEGISLATION

The most advantageous tender committee is composed of experts for evaluation and selection (Legislative Law 370/1995), while taking technology, quality, function, price etc into evaluation items. In recent Legislative Law 394/1996, the committee identifies weighting criteria for each case and for cases of the same kind in each organization the same committee is used and sometimes the same weights. It is a kind of group decision making policy during evaluations. Therefore, how to adopt the quantitative methods properly combining the different opinions in weights is the major concern of the most advantageous tender system.

Laws and regulation for the existing ranking method

In accordance with the Greek Legislative Law concerning Regulations for Evaluation of the Most Advantageous Tender (Legislative Law 2286/1995), the criteria weights that refer to the ranks or scores given to the tenders by the evaluation committee are published in the Legislative Journal documentation. By adoption the ranking method, the most advantageous tender is determined mostly according to the importance or weights of evaluation items by the head of the procuring entity or the concurrence of the majority of the evaluation committee. After compiling the evaluation of all criteria for all tenders from all committee members, the one with the best ranking is the known as the ranking first tender. Moreover, in order to ensure certain credibility of the evaluation a table with the calculation of scores is presented to the tenders. This procedure is recorded in this study and compared with the proposed method.

Reviews on the existing laws and regulations

The aforementioned discussion reveals that the related regulations of the current ranking methods are mainly about selecting and evaluating the criteria in terms of weights. However, this method is merely arbitrary and obviously has the following drawbacks:

1. It has being easily subjected to the influences of biased weights evaluations of a small number of committee members: If a few of the committee members give a particular criterion the best or the worst weight, however, it is very likely to result in biased evaluations.
2. There are still no laws to follow in actual executions. Some agencies have not tested the consistency of evaluation result among committee members. As a result, regulations remain a routine paperwork with no actual functions.

LITERATURE REVIEW ON EXISTING METHODS

In this section, we present the results of an extensive literature search on criteria weights in decision support for grouped case supplier selection. In the literature, extensive work is noticed on research based on historical data and the buyer's experience current or familiar suppliers are evaluated on a set of criteria (Zenz 1981; Timmerman 1986). The evaluations actually consist of categorizing the supplier's performance on a criterion as either 'positive', 'neutral' or 'negative'. After a supplier has been rated on all criteria, the buyer gives an overall rating, again through ticking one of the three options. In this way, suppliers are sorted into three categories. The so-called linear weighting models weights are given to the criteria, the biggest weight indicating the highest importance. Ratings on the criteria are multiplied by their weights and summed in order to obtain a single figure for each supplier. The supplier with the highest overall rating can then be selected. This basic linear weighting model is described mostly in purchasing textbooks. De Boer *et al*. (1998) use the outranking approach. This approach, among other things, allows the buyer to specify in advance limits to the compensation for bad scores on one or more criteria. In a rating model Nydick and Hill (1992), Barbarosoglu and Yazgaç (1997), Narasimhan (1983) and Narsimhan and Stoyno (1986) propose the use of the analytic hierarchy process (AHP), a method of MCDM, to deal with imprecision in supplier choice. AHP circumvents the difficulty of having to provide point estimates for criteria weights as well as performance scores in the basic linear weighting model. Sarkis and Talluri (2000) propose the use of the analytical network process (ANP), a more sophisticated version of AHP, for supplier selection. Willis *et al*. (1993) use such pair-wise comparisons among suppliers, measuring each criterion in terms of its specific unit of analysis. Another group of authors has suggested various statistical techniques to deal with imprecision when using linear weighting models. Williams (1984) proposes the use of conjoint-analysis in deriving criteria weights. Min (1994) and Petroni and Braglia (2000), apply the so-called 'indifference trade-off' method and principal component analysis for essentially the same purpose. The vast majority of the publications found on criteria weights seem to have been written in the context of selecting a supplier for the purchase of a product to be used. The existing articles on methods for supplier selection do not sufficiently address this contextual issue. Often they assume, explicitly or implicitly, that their method is applicable in all purchasing contexts. At most, a reference is made to a particular industry in which a method has been empirically tested or the need to change the criteria considered when applying the method to another type of product.

PROPOSED METHOD

Our framework addresses a practical approach of fuzzy sets theory in order to be applicable in categorized purchasing contexts. In doing so, characteristics like the type of procurement, the product and the phasing and organization of the whole supplier selection process are clustered by using historic information. Similar approaches, such as Cluster Analysis (CA, Hinkle *et al*. 1969; Holt 1998), consist of a basic method from statistics that uses a classification algorithm to group a number of items that are described by a set of numerical attribute scores into a number of clusters so that the differences between items within a cluster are minimal and the differences between items from different clusters are maximal. Also artificial intelligence approaches and specifically case-based-reasoning (CBR) are software-driven database systems that provide a decision-maker with useful information and experiences from similar, previous decision situations. A CBR is still very new and only few systems have been developed for purchasing decision-making. Between these pioneer studies, Ng and Skitmore (1995) developed a CBR system for the pre-qualification of suppliers.

The applications of knowledge management vendor selection, which may be generated from or adapted to fuzzy sets theory and fuzzy logic, are wide-ranging. Fuzzy logic is a new approach to the analysis of problems too complex to be susceptible to analysis by conventional methods. It is an entirely non-numeric approach that allows user to make verbal judgments through natural language expressions like ‘very good’, ‘somewhat poor’, etc.

Such fuzzy judgments are then quantified using the extension principle applied to fuzzy set theory (Zadeh 1975). Mathematical theory of fuzzy sets forms a promising approach to bridge this gap between technically necessary precision and the empirically more appropriate, but imprecise description of the problem (Zadeh 1975). Based on the aforementioned drawbacks for the problem considered in our study, Kumar and Shankar (2004) propose an improved ranking procedure to choose the supplier as the most advantageous tender. Also another characteristic paper from Noorul and Kannan (2005) aims to demonstrate how the fuzzy model can help in solving such decisions in practice. Similarly fuzzy goal programming approach is applied in the paper of Michailov (2004) for solving the vendor selection problem with multiple objectives, in which some of the parameters are fuzzy in nature.

In the following paragraphs, a methodological framework based on fuzzy sets theory for vendor selection is selected since the existing data are unreliable and unavailable in the Greek databases. It is divided into two sections. First, the methodology to estimate the criteria weights is presented then the comparison of results of the method used to incorporate these criteria weights and those of the existing multiple criteria decision making procedure follows.

Estimation of criteria weights

Fuzzy sets theory is a useful tool for dealing with vendor selection, taking into account uncertainty in the interpretation of alternatives, particularly when there is a group of similar procurement cases. These and other problems of integration of fuzzy set methods to vendor selection are discussed in many top-ranking international journals. Using this theory in the procurement process, we take into account technical, ecological and economic factors. In this case, the knowledge management fuzzy model is based on a multi-criteria theory of multiple vendors and choice of alternatives.

Definition 1. Let X be a set (universe). D is called a fuzzy subset of X if D is a set of ordered pairs: $D = [(x, \mu_D(x)), x \in X]$, where $\mu_D(x)$ is the grade of membership of X in D. $\mu_D(x)$ takes its values in the closed interval [0,1]. The closer $\mu_D(x)$ is to 1, the more x belongs to D; the closer it is to 0 the less it belongs to D. If [0,1] is replaced by the two element set {0,1}, then D can be regarded as a subset of X.

Definition 2. The α level set of fuzzy subset D is the set of those elements that have at least a membership: $D(\alpha) = [x: \mu_D(x) \geq \alpha]$. A fuzzy subset n^* is called normal if there is at least one z such that $z_{n^*}(z) = 1$.

In particular, consider that there is a set of m vendors as described in equation (1):

$$A=\{a_1, a_2, \ldots a_m\} \tag{1}$$

and a fuzzy set of criteria described in equation (2):

$$C=\{\mu_c(a_1)/a_1, \mu_c(a_2)/a_2, \ldots, \mu_c(a_m)/a_m\} \tag{2}$$

where the membership function $\mu_c(a_i)$ expresses the experts knowledge about grade vendors satisfaction to criteria C.

If there are several criteria $C_1, C_2, ..., C_n$ and the coefficients of relative significance of these criteria are $\alpha_1, \alpha_2, \ldots \alpha_n$, the rule for selection of the best vendor selection taking into account α_i will be written as intersection of C_i

$$D = \left(C_1^* \cap C_2^* \cap \ldots C_n^*\right) \tag{3}$$

where

$$C_1^* = \left(C_1^{\alpha_i}, a_i \geq 0\right) i=1,\cdots,n, \frac{1}{n}\sum_{i=1}^{n} a_i = 1 \tag{4}$$

The coefficients of relative significance α_i are found by comparison of pairs of criteria. Assume now a ixj matrix B each of the elements b_{ij} of this matrix corresponds to the relative importance of criterion i to criterion j. These elements must satisfy the condition: $b_{ij} = 1/b_{ji}$ .The value of elements b_{ij} of matrix B has a scale from 0 to 9 and is defined in Table 1. For example, the element $b_{ij} = 1$ if the scale of evaluation of relative importance of criteria C_i and C_j is that of equilibrium; the element $b_{ij} = 9$ if the scale of evaluation of relative importance of criteria C_i and C_j is that of great importance.

Table 1: Scale of evaluation of relative importance of criteria

Relative importance of criteria C_i and C_j	**Element b_{ij}**
Equilibrium	1
Very of little importance	3
Of little importance	5
Importance	7
Great importance	9
Intermediate values	2,4,6,8

Next, the self-vector of the matrix B is determined from the solution of equation (5):

$$Bw = \lambda_{max} w \tag{5}$$

where λ_{max} is maximum of self-number of the matrix. The solution sought is given by $\alpha_i = n\, w_i$, where n is a predefined number of i criterion and w is the corresponding weight.

The mathematical operation of intersection of fuzzy sets is in agreement with operation of the search for minimum of the membership functions of these fuzzy sets.

In this specific problem, preference is given to vendors that are characterized by the greatest value of the membership function.

Multiple assessment in this example was carried out by four criteria:

- Economical criteria (EC).
- Technological criteria (TC).
- Item delivery criteria (IDC).
- Service criteria (SC).

As an example of the above criteria, consider the procurement of an excavation equipment. The economical efficiency of vendors may be the price and purchases done during the past three years. The technical criteria might be the capacity of the excavation equipment, emissions, noise when working and when idling etc. consumption The delivery time, ability to deliver on time belong to the item delivery criteria while service criteria SC might be warranty, after sales service etc.

Since we deal with parameters that are not always measured in monetary units a normalization procedure *R(x)* is used to convert the non-monetary units to a 0 to 1 scale. The normalized value *R(x)* – key link between non-monetary units and an 0 to 1 relationship – is given by the equation:

$$R(x) = \left| \frac{R(i) - Rj}{R(i) - R(w)} \right| \tag{6}$$

where *R(i)* is the ideal value, *R(w)* is the worst value and R_j is the value of j criterion where j corresponds to the 1 to 4 i.e. the EC, TC, IDC, and SC value of the alternative.

Specifically:

With the EC, we evaluate the economical efficiency of vendor characteristics. EC =1, if the characteristics are economically efficient; EC = 0, if they are not.

With the TC, we try to evaluate vendor characteristics and the feasibility of these TC =1, if the characteristics are fully suitable; TC = 0, if they are not.

With the IDC, we evaluate the additional negative effects of the proposed alternative. IDC =1, if the negative effect is absent, ECC = 0, if it is not.

SC provides an estimate of the service factors. SC =1, if the response is positive; SC = 0, if the response is negative.

Incorporation of criteria weights into the multi criteria decision making

The procedure that is following is used to incorporate the above criteria to the vendor selection as well as to compare the results with the existing evaluation. This can be achieved by adopting a MCDM technique (i.e. AHP). MCDM is widely used in urban and regional planning and is a useful methodology in arranging available information concerning choice possibilities (Nijkamp *et al*. 1990). MCDM is a technique designed to value two or more criteria. It is particularly useful for evaluation criteria that cannot be easily quantified in normal market transactions. It uses the approach of applying weights to these impacts to determine a preferred outcome. MCDM involves measuring criteria values such as, delivery time, service time etc., in normalized units that are then turned into comparative value functions. Therefore, due to the fact that some of the above cannot be assessed in economic terms, the MCDM techniques of weighting and ranking are applied to value services, which are often in non-monetary terms. The total scores using a comprehensive application of AHP for a real-world case is presented along with the analysis to choose the best supplier in order to rank project alternatives and arrive at a decision accordingly. Emphasis, therefore, is placed on the identification of criteria, namely the economical criteria (EC), technological criteria (TC), item delivery criteria (IDC), service criteria (SC) and the measurement and incorporation of these criteria in the project evaluation process. The model is formulated as follows:

$$MCDM(i)=I_{EC}* W_{EC} +I_{TC}* W_{TC} +I_{IDC}* W_{ITC} +I_{SC}* W_{SC} \tag{7}$$

where

i is the alternative number I_{EC}, I_{TC}, I_{IDC}, and I_{SC} denote respectively the contribution of economical criteria (EC), technological criteria (TC), item delivery criteria (IDC), service criteria (SC) indices to the overall index MCDM(i) and

W_{EC}, W_{TC}, W_{ITC}, W_{EC} are the criteria weights

and

$$I_{EC}, I_{TC}, I_{IDC}, I_{SC} \in (0,1)$$

$$W_{EC}, +W_{TC}, +W_{ITC}, +W_{EC} =1 \tag{8}$$

CASE STUDY

A case study is described where there is need for vendor selection as grouped for excavation equipment and is a real case. There were four vendors differing in terms of the of the committee economic criteria, (EC) technical criteria (TC), item delivery criteria (IDC) and service criteria (SC) indices. The figures presented in the next of the study are normalized.

Application of the proposed model

The pair wise values of the economic criteria (EC), technical criteria (TC), item delivery criteria (IDC) and service criteria (SC) are presented in Table 2.

Table 2: Values of the four criteria assigned by an expert panel

VENDOR	Criteria			
	EC	TC	IDC	SC
1	1	1	1	1
2	0.5	2	0.5	2
3	0.8	3	0.8	3
4	0.7	0.6	1	0.6

The coefficients of relative significance α_i are found by comparison of pair of criteria. To start this assessment, the coefficients of relative importance are initially entered into matrix B. Elements bij of matrix B are tabulated in equation 9.

$$B = \begin{bmatrix} 1 & 5 & 6 & 7 \\ 1/5 & 1 & 4 & 6 \\ 1/6 & 1/4 & 1 & 4 \\ 1/7 & 1/6 & 1/4 & 1 \end{bmatrix} \tag{9}$$

The criteria weights as components of self-vector of the matrix with λ_{max} = 4.390 are as follows: W_{EC} = 0.619, W_{TC}= 0.235, W_{ITC} = 0.101, W_{EC} = 0.045.

Incorporation of criteria weights into the multi criteria decision making

Table 3. Results of the proposed model

VENDOR	EC* W_{EC}	TC* W_{TC}	IDC* W_{ITC}	SC* W_{EC}	Overall Index
1	0.619	0.211	0.081	0.036	0.947
2	0.309	0.094	0.101	0.0315	0.536
3	0.495	0.211	0.101	0.045	0.852
4	0.433	0.141	0.101	0.027	0.702

Application of the existing method
The values were taken from the committee members' estimation according to the Greek Legislative Law.

The corresponding weights to the above according to the experts' opinions are as follows: WEC = 0.60, WTC = 0.20, W_{ITC} = 0.10, W_{EC} = 0.10.

Table 4: Results of the existing procedure

VENDOR	EC* W_{EC}	TC* W_{TC}	IDC* W_{ITC}	SC* W_{EC}	Overall Index
1	0.6	0.18	0.08	0.08	0.94
2	0.3	0.08	0.1	0.07	0.55
3	0.48	0.18	0.1	0.1	0.86
4	0.42	0.12	0.1	0.06	0.7

Comparison of the proposed model and the existing procedure and discussion
For the case study considered, the first vendor scores high in both the proposed model (with a score of 0.9473) and the existing procedure (with a score of 0.94) and is more advantageous according to the criteria rating and weights developed. This is due to the similarity of the weights of economic criteria, technical criteria and item delivery criteria (0.619 to 0.60; 0.235 to 0.20; and 0.101 to 0.10, respectively) though there is a difference in service criteria (0.045 to 0.10) that derived somehow similar to the solution when the Legislative Law Indicative weights are followed. As can be seen, the correct calculation of the weights is the key element of the procedures discussed. The arbitrary determination of the weights in the existing procedure may lead to bias of the method.

CONCLUSIONS

This research proposes an improved evaluation procedure based on the utilization of fuzzy sets that can be used in real procurement cases. These cases are categorized to certain groups so that the methodology can be applied to a number of similar cases. It is also a practical approach because with analysis of a particular procurement case, the result can be utilized in a number of similar cases in terms of criteria weights of the methodology and not on arbitrary identification. This improved procedure not only possesses theoretical foundations, but also it enables the testing on the consistency in group evaluation results and complies with the Greek Legislative Law and the EU directives. It can also evaluate differences among individual and committee members, as the results take into account the experts' opinions and can be used as a tool to adopt the quantitative methods properly combining the different opinions of the evaluation committee members in order to represent the overall evaluation. Using different weight criteria for each case, the improved procedure is able to lower the impacts of deviated evaluation of individual committee members as well as reduce such biased evaluation to some particular suppliers. Therefore, this improved procedure may enhance the quality in determining the most advantageous tender. The further development of this approach could create a methodological framework for vendor selection processes.

REFERENCES

Barbarosoglu, G and Yazgac, T (1997) An application of the analytic hierarchy process to the supplier selection problem. *Production and Inventory Management Journal*, **1st quarter**, 14–21.

De Boer, L (1998) *Operations research in support of purchasing. Design of a toolbox for supplier selection*, Unpublished PhD Thesis, University of Twente, Enschede, The Netherlands.

Handfield, R B, Walton, S V, Sroufe, R and Melynyk, S A, (2002) Applying environmental criteria to supplier assessment: application of the analytical hierarchy process. *European Journal of Operational Research*, **141**, 70–87.

Hinkle, C L, Robinson, P J and Green P E, (1969) Vendor evaluation using cluster analysis. *Journal of Purchasing*, **5**(3), 49–58.

Holt, G D (1998) Which contractor selection methodology? *International Journal of Project Management*, **16**(3), 153–64.

Kumar M and Shankar P V (2004) A fuzzy goal programming approach for vendor selection problem in a supply chain. *Computers and Industrial Engineering*, **46**(1), 69–85.

Legislative Law 2286 (1995) Public Procurement and Related Regulations (in Greek). *Greek Government Official Journal*, **266**(1), 1925–31.

Legislative Law 370 (1995) Harmonization of Greek Legislation to EC Directive 93/36/EC (in Greek). *Greek Government Official Journal*, **199**(1), 5625–39.

Legislative Law 394 (1996) Public Procurement and Related Regulations (in Greek). *Greek Government Official Journal*, **19**(1), 4689–890.

Mikhailov, L (2004) Group prioritization in the AHP by fuzzy preference programming method. *Computers and Operations Research*, **31**(2), 68–78.

Min, H (1994) International supplier selection: a multi-attribute utility approach. *International Journal of Physical Distribution & Logistics Management*, **24**(5), 24–33.

Narasimhan, R (1983) An analytic approach to supplier selection. *Journal of Purchasing and Supply Management*, **6**(1), 27–32.

Narsimhan, R and Stoyno L K (1986) Optimizing Aggregate Procurement Allocation Decisions. *Journal of Purchasing and Materials Management*, **22** (1), 23–30.

Noorul, A H and Kannan, G. (2005) Fuzzy analytical hierarchy process for evaluating and selecting a vendor in a supply chain model. *Computer Science and Engineering* **29** (7–8), 826–35.

Ng, S T and Skitmore, R M (1995) CP-DSS: decision support system for contractor prequalification. *Civil Engineering Systems: Decision Making Problem Solving*, **12**(2), 133–60.

Nijkamp, P, Rietveld, P and Voogd, H (1990) *Multicriteria Evaluation in Physical Planning*. North Holland.

Nydick, R L and Hill, R P (1992) Using the Analytic Hierarchy Process to structure the supplier selection procedure. *International Journal of Purchasing and Materials Management*, **28**(2), 31–6.

Petroni, A and Braglia M (2000) Vendor selection using principal component analysis. *The Journal of Supply Chain Management: A G1obal Review of Purchasing and Supply*, **36**(2), 63–9.

Sarkis, J and Talluri S (2000) A model for strategic supplier selection. *In:* Leenders, M, (Ed.) *9th International IPSERA Conference.* Richard Ivey Business School, London, Ontario, 652–61.

Timmerman, E (1986) An approach to vendor performance evaluation. *Journal of Purchasing and Supply Management*,**1**, 27–32.

Verma, R and Pullman, M E (1998) An Analysis of Supplier Selection Process. *International Journal of Management Science*, **26**(6), 739–50.

Williams, R F (1984) *Purchasing the technological product: selecting and weighting criteria for the inherently complex new product*. Ann Arbor, MI: University Microfilms International.

Willis, T H, Huston, C R and Pohlkamp, F (1993). Evaluation measures of just-in-time supplier performance. *Production and Inventory Management Journal,* **2nd quarter**, 1–5.

Zadeh, L A (1975) Fuzzy sets. *Information Controlling*, **8**(3), 338–53.

Zenz, G (1981) *Purchasing and the Management of Materials.* New York: John Wiley & Sons.

TOTAL QUALITY MANAGEMENT IN CONSTRUCTION: A CASE OF JORDAN

Ayman H. Al-Momani[1]

Civil Engineering Department, Mu'tah University, Mu'tah PO Box 7, Karak, Jordan

This paper proposes to investigate the status of construction industry in Jordan, report an overview of TQM initiatives in Jordan and attempt to develop assessment model of performance for local contractors to respond to market pressures caused by the size and complexity of new construction projects. The developed model has the potential to enable contractors to build on existing quality management systems and provide useful practical guidance that compels the organization to seek a new level of excellence. Potential to achieving the required organizational environment is explored, and the criteria mentioned in the model are taking place. TQM is a desired culture of an organization committed to customer satisfaction. The more conscious the contractors are about the requirements mentioned in the model, the better the chances are for their the project's success. Such initiatives are necessary to meet customer requirements and to help construction companies to survive and face increasing competition.

Keywords: award for excellence, construction industry, Jordan, performance assessment, TQM.

INTRODUCTION

Quality is a major concern for all sectors of the national economy, including construction. The concepts have changed over the decades. Having focused on the concept of quality control in the 1950s and 1960s, and on the concept of quality assurance from the mid 1960s until the beginning of the 1980s, it is the concept of total quality management (TQM) which is now on the agenda.

The construction industry has many problems because of its complicated nature of operation. This industry is comprised of a multitude of occupations, professions and organizations (Kanj and Wong 1998; Milakovich 1995; Sommerville 1994). Projects require the involvement of larger number of specialists in design, fabrication, construction, and operation and maintenance, each contributing necessary pieces to the product development process (Gil *et al*. 1999). This involvement prevails in different phases, which include: feasibility, development, construction and start-up (Schultzel and Unruh 1996). Goals tend to conflict as different parties have different priorities (Wong and Fung 1999). Similarly, Himes (1995) emphasized that the construction industry has a reputation of conflict, mistrust, claims and litigation.

The key element needed for organizational success is the ability to identify what is changing in the environment and to respond proactively through continuous improvement efforts (Brown and Eisenhardt 2000). One form of operations management practices is total quality management (TQM), which has received a growing amount of attention in the last two decades (Jung and Wang 2006). The

[1] ahmomani@mutah.edu.jo

primary aim of a quality system is to prevent non-conformity at all stages of a project and, as a result, the control of non-conformances, waste and quality loss reduction should become a focal point in any organization's quality improvement efforts. Non-conformities can include any kind of deviation from the ‘specified requirements’, and may be in the form of failure, waste, defect, error and any other loss that might prevent a product or service from meeting its ‘fitness for purpose or use’ and ‘customer satisfaction’ (Smith *et al*. 1999)

Partnering, supply chain management (SCM) and total quality management (TQM) are all concepts or approaches that can be applied as initiatives to solve problems in the construction industry and meet the needs of customers (Kanji and Wong 1998). TQM is also a philosophy that helps to improve all aspects of an organization and is aimed at exceeding customer expectations (McIntyre and Kirschenman 2000). Despite this unwillingness, Lahndt (1999) stated that the construction sector had begun to realize the importance of TQM and that quality had become a main construction goal. Cheetham (1993) has indicated that quality systems in the construction industry perform two valuable functions. The first is, by their very existence, raising the level of quality awareness throughout the company. This, in turn, can favourably influence attitudes towards quality on the part of the employees. The second function is to enable certification: a certified system being a tool that enables a company to compete in an increasingly quality conscious market.

The importance of TQM in construction firms is widely acknowledged today (Saha and Hardie 2005; Jaffari 1996; Love *et al*. 2000; Walker and Keniger 2002). Analysed within the multiple stakeholder perspective, TQM has a significant impact on the organization itself, its survival and profitability, the customers, the suppliers, the social context, and the employees (Henry 2000; Serpell *et al*. 2002; Jahren and Federle 1999). As pointed out by Xiao and Proverbs (2002), adapting TQM creates a culture of trust, participation, teamwork, quality-mindedness, eagerness for continuous improvement, continuous learning and, ultimately, a working culture that contributes towards a firm’s success and existence.

Total quality has long been practiced in the developed countries such as Japan, USA and UK. Construction quality in Japan has improved greatly since the introduction of TQM in the 1970s (Bennet *et al*. 1987). More and more construction companies are adopting TQM to improve their performance (Kanji and Wong 1998; Fung and Wong 1995; Jido 1996; Sommerville 1994). Much evidence is now emerging to show that TQM does deliver improved performance when implemented effectively (Hendricks and Singhal 2001; Easton and Jarrel 1998). A longitudinal study of TQM implementation by Taylor and Wright (2003) highlighted some necessary antecedents for TQM success. In particular, mangers need to understand the nature and purpose of TQM, and the potential benefits that can accrue from its implementation (Taylor and Wright 2003).

THE CONTROVERSY ABOUT THE VALUE OF TQM

TQM has recently been getting a bad rap in the popular business press regarding its ability to improve financial performance. Mixed results on outcomes have been reported in literature: the adoption of the TQM marginally affects actual improvement of organizational performance (Broetzmann *et al*. 1995) and the relationship of TQM practice is positively associated with operational performance measures (Chi and Eboch 1998). The launch of the Malcolm Baldrige National Quality Award

(MBNQA) framework in 1995 narrowed the number of disputes on what elements TQM practices. Many researchers have based their work on MBNQA criteria (Jung and Wang 2006).

REASONS FOR PURSUING TQM

Jordan is still in the developing stages of TQM and the concepts are being slowly adopted. The construction sector generally has lagged behind other industries in practising and implementing TQM. In many cases, creating drawings with a minimum number of errors, fulfilling the requirements of a contract and defining technical specifications do not guarantee the quality required by owner. Therefore, quality initiatives in Jordan and the launching of the award for excellence provide an opportunity for contractors and designers to renovate their practices and information on quality management.

The construction industry will not last long in its present state of isolation, where it is completely out of touch with initiatives centred on quality. Therefore, fundamental changes in current practices of construction are required. These changes go to both operational and national levels. Leaders and top management should create an environment that fosters participation of construction contractors and designers to incorporate the factors affecting quality practices.

RESEARCH OBJECTIVES

Leonard and McAdam (2002) observed that most of the existing models are operational level focused. There is a need for models to be used at the strategic level in terms of planning and longitudinal planning. However, TQM is a new concept introduced in Jordan. The present study comprised one of the early stages of major construction investigation that was undertaken to improve overall quality of construction. The objective of this research is to focus on the status of the construction industry in Jordan, report an overview of TQM initiatives in Jordan and attempt to develop a performance assessment model for local contractors to respond to market pressures caused by the size and complexity of projects.

Such initiatives will be necessary to meet customer requirements, and to help construction companies to survive and thrive in the face of ever-increasing competition.

CONSTRUCTION INDUSTRY IN JORDAN

The construction industry is unique because of differences in management practices and construction methods both between countries and within the industry itself. Both design and construction team members are different for each project (Low and Tan 1996). Continuously changing customers’ needs adds to the peculiarity of construction projects. In 2005, the Jordanian economy successfully achieved a high growth rate in the real Gross Domestic Product (GDP), exceeding the population growth, reaching 7.2% as compared to 7.7% in 2004. The construction industry in Jordan and the associated income arising from it witnessed a boom during the past six years due largely to the significant infrastructure and real estate investments made, especially in housing development and tourism projects. This sector is the sixth largest employer in the country, employing more than 7% of the total labour force with an annual turnover accounting for approximately 8% of GDP (Export & Finance Bank 2003).

The favourable sentiment in the sector was reflected by the 55.3% rise in new firms. A total of 73 new construction-related companies were established in year 2005 compared to 47 new firms in 2004, while the aggregate capital of new firms increased by 19% to JD 3.1 million year-on-year. Reflecting construction activity and in line with government expansionary credit policy, bank credits extended to construction during the first half of 2005 surged by 143.3% to JD 115 million, driven by a 225% jump in the second quarter of the year relative to the same period last year (Audi Bank 2005).

Public spending on construction projects is the most important factor behind the growth in the construction sector in Jordan, followed closely by private construction investment. The Ministry of Planning is responsible for allocation of the majority of construction projects throughout the Kingdom and therefore receives the largest share of allocated funds. The Ministry of Public Works is the main conduit for government spending on infrastructure projects. A number of public institutions connected to the Ministry share the role of regulating the sector in Jordan such as: Tenders Department; Contractors Associations; Engineering Association; and Housing and Urban Development Corporation.

The country has gone through massive structural and large-scale projects. These projects were mainly in the fields of transportation, tourism, education and health, i.e. highways, airports, the Port of Aqaba, hotels, schools, and hospitals, as well as water projects. A number of large real estate projects have been launched, the largest of which are the US$ 1.0 billion Royal Metropolis, the US$ 620 million Saraya Aqaba developments and the US$ 340 million Abdali Investment and Development Project. These projects involve the construction of hotels, commercial, residential, retail and entertainment facilities. Jordanian contractors and consultants have had minimal involvement in such large-scale projects, while foreign contractors were profoundly involved. This might have been because foreign contractors are considerably more experienced and skilled than local contractors are.

The construction sector faces many performance problems such as delays; numerous design changes; increased quantities; payment delays; improper planning; escalating costs; shortages of materials; poor contract management; and inadequate contractor experience (Al-Momani 2000). The volume of work carried out by the construction sector shows sharp fluctuations over the years. This may be attributed to many factors such as: limited available funds, lack of sound institutional and legal frameworks; administrative and allocation inefficiencies; management and financial inadequacies; and the political uncertainty that has overshadowed the region. In this context, poor construction quality damages the competitiveness of the nation's industries.

Pressure to improve quality

In the light of the difficulties facing construction contractors in their performance, they have encountered much pressure to improve quality that is explained below:

- *First:* construction increasingly is a complex process, with a plea for participation of specialized professionals, contractors, sub-contractors and suppliers to deliver a project. Therefore, the client will come into contact with many agents to ensure best performance. This calls for collaborative management efforts and coordination on their part. Structured relationship will facilitate the achievement of TQM requirements.

- *Second*: the media responds and enhances the growing interest in the demand for quality construction, as well as publicizing the newsworthy examples of quality.
- *Third*, rising standards of living increases consumerism and choices, and change is evident in clients' expectations. Clients increasingly expect the same service from construction industry.
- *Fourth*, tremendous growth in the use of quality methods in other sectors have led to quality thrusts nationally and internationally.

Higher customer satisfaction, better quality products and higher market share are obtained if the construction companies adopt TQM in their operation (Kanji and Wang 1998). These concerns shed lights on importance of TQM in construction in this research.

Improving construction quality

As a result of different pressures, there have been a number of initiatives in Jordan to ensure and improve construction quality. The Kingdom of Jordan joined the quality race in 2000. Below is a list of these initiatives:

- Professional initiatives, such as standard setting, training, and audit methods.
- Governmental regulations such as licensing and inspection.
- Establishing a department of specification and standards, and a quality control units promoted by professional and some governmental units.
- National quality and performance strategies.
- Quality prizes and awards
- Patent information, participation and rights.
- ISO 9000 Registration.
- Total quality management (TQM).

In addition, the government is well placed to understand what constitutes best practice and extend the learning throughout the industry.

STRUCTURE OF KING ABDULLAH II AWARD FOR EXCELLENCE

Award background and objectives

Adebanjo (2001) asserts that business excellence and quality complement each other and should co-exist. For the purpose of this paper, the King Abdullah II Award for Excellence (KAAE) is used. The King Abdullah II Award for Excellence (KAAE) is the highest level of quality recognition in Jordan. The award was developed by the Industrial Development Directorate (IDD) at the Ministry of Industry and Trade, and the Jordan-United States Business Partnership (JUSBP) administered by the International Executive Services Corporation (IESC), and funded by the US Agency for International Development (USAID). The award is granted once every two years and divides participating firms into five main categories:

- Large manufacturing companies.

- Small- to medium-size manufacturing companies (less or equal to 50 employees).
- Large service organizations.
- Small- to medium-service firms (less or equal to 100 employees).
- Newly added agriculture and agricultural marketing organizations category.

The criteria are divided into enablers and results. The award is characterized by a concept that consists of five distinctive areas, each representing a different aspect of the organization. The enablers cover leadership, strategic planning, processes management, resources management and results. The "results" are separated into business results, products and costumer satisfaction**.** These five areas are divided into sub-areas concerned with the achieved results and areas concerned with how these results have been achieved (enablers). As a whole, an enterprise can achieve a total of 1,000 points whereby the different areas are weighed according to their relative importance (Table 1). The model consists of an integrated cycle of continuous improvement. The cycle starts with self-assessment of results and, on the basis of the findings, an organization can decide what actions can be taken to strengthen enablers to improve the results. The company that wins the competition is entitled to use the quality label of the King Abdullah II Award for Excellence in advertisements and publications.

Table 1: The evaluation criteria of the King Abdullah II Award for Excellence (KAAE)

Leadership	150
Strategic Planning	150
Resource Management	250
Process Management	200
Results	250
TOTAL POINTS	1000

The award aims to create qualitative transformation and to develop the performance of government and institutions in serving Jordanian citizens and investors, as well as to enhance positive competitiveness among government departments and institutions through promoting awareness of the concepts of distinguished performance, innovation and quality, and establishing the culture of excellence that is founded for best practice. The award strives to assist organizations to achieve overall competitiveness; good governance; satisfied customers, suppliers and partners; committed employee involvement; community approval; and significant gains in business results and productivity. The award has gained broad acceptance among both profit and non-profit organizations.

STRUCTURE OF PERFORMANCE ASSESSMENT MODEL FOR LOCAL CONTRACTORS

As outlined by Dale (1999), business excellence in its pure undiluted form is based on TQM and, as such, should incorporate all its facets and this should be recognized. Stading and Vokurka (2003) stated that the international community is generally evolving toward a common set of beliefs about the TQM process. This becomes a source of competitive advantage for individual firms competing in the global marketplace if content is considered and appropriately weighted.

The conceptual model for this study is graphically depicted in Figure 1. The ‘fundamental concepts’ underpinning the Excellence Model reflect its total quality origin. The model has five core precepts: leadership, strategic planning, process management, resources management and results.

The award criteria are built on common beliefs of a TQM strategy process. The nature of these precepts shows the quality issues in construction industry from both project and industry levels. Using the model, a multidisciplinary team is formulated. Their objective is the development of a TQM environment. The project quality management environment is established in stage 1, and a path foreword TQM deployment plan is determined in stage 2 (knowledge-skill development and product-process development). In stage 2, the owner, designer and the contractor begin the alignment process by reviewing the project's technical requirements. A multidisciplinary team is empowered to make the necessary improvements to the project, identify problems, allocate risk and become involved in process change. This stage could require training requirements. Once the mutual understanding is achieved, the team must align the TQM requirements and involvement of all members.

Managers use cross-functional work teams to break down long-standing barriers, improve effectiveness and meet goals. They will have to participate in activities such as promoting innovation, encouraging team activities, close working relationships, and meeting with owner, contractor and suppliers. Key quality management elements of stage 2 are again performed during stage 3. In this stage, two main issues include aligning the project vision and mission with the customer needs and expectations. The project team must integrate the TQM concepts to the project from its inception to its completion. In stage 4, the team applies the concepts of continuous improvement to the project. Incorporating the principles of continuous improvement via the PDCA cycle into the plan is indispensable for TQM principles to flourish.

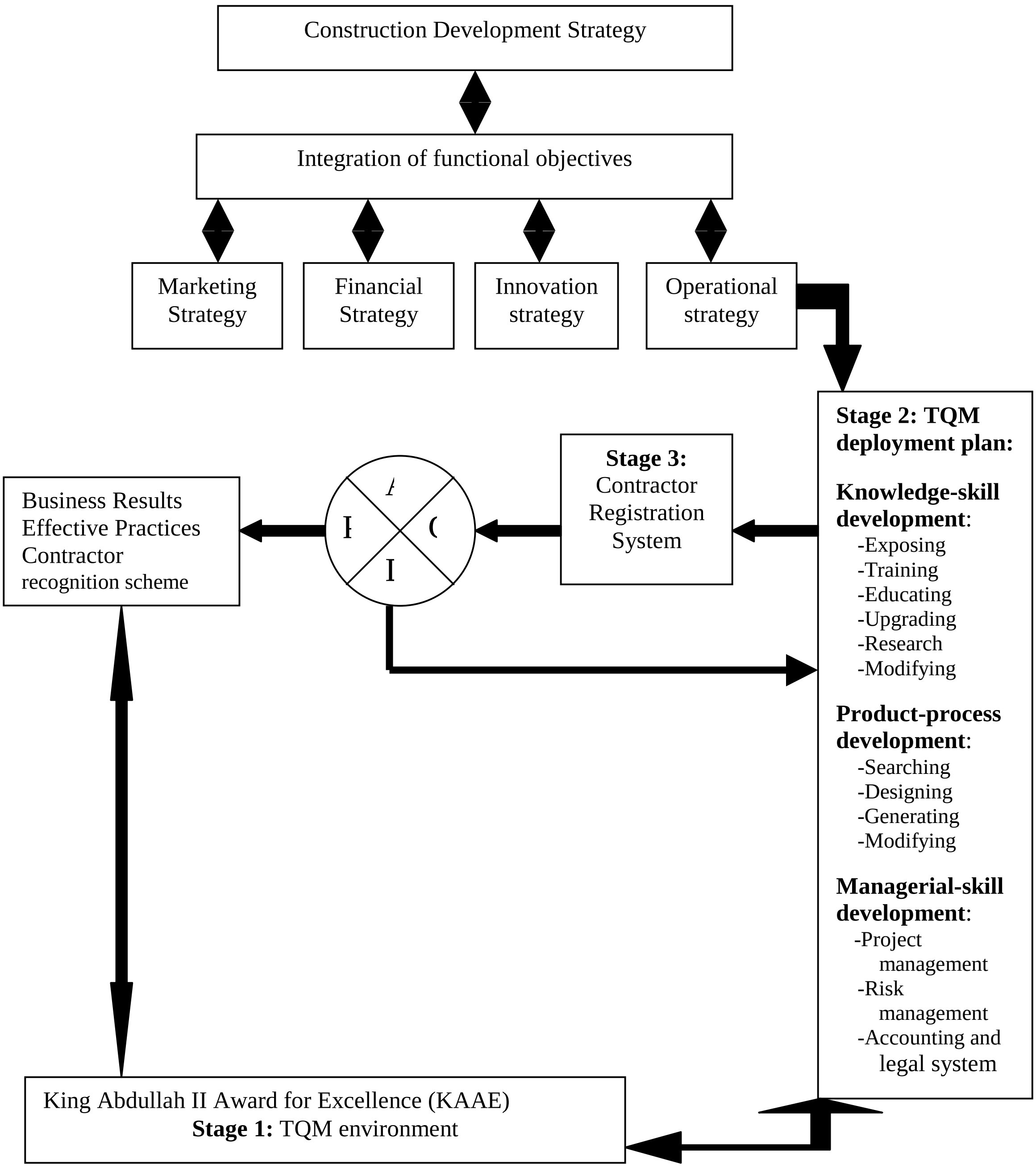


Figure 1: The structure of performance assessment model for local contractors

Once the plan is deployed, the team must periodically assess and review the results of applying TQM. Based on periodic reviews, the management team must adjust the TQM plan to encourage improvement. This enables managers to take remedial action before tolerance limits are exceeded and begin to impact on construction delivery. This stage examines the organization's performance and improvement in key business areas, customer satisfaction, financial performance, human resource results, supplier and partner results, and operational performance. Compensation, recognition, and rewards are provided for results, such as submitting improvement ideas for reductions in cycle time and at less-than-projected cost. The model will help to develop an ethos where managers, project team member and contractors perform together which means they are able jointly to look at the way the process is carried out and take improvement action if necessary.

The implementation of the model would gain a line of its own within the construction sector. The model has the potential to enable contractors to build on existing quality management systems for ways to achieve excellence in the construction and assessment process. In the light of the above, specific potential benefits that are offered by the model may be summarised as follows:

- *First*, the King Abdullah II Award for Excellence (KAAE) can be implemented in harmony with the contractor's assessment process, although they each have a unique role in determining different types of performance.
- *Second*, the compatibility of KAAE and the contractor's assessment process can be adopted to build contractors competence and capabilities; this is in line with findings reported in other studies.
- *Third*, the integration between contractor's assessment process and (KAAE) is and innovative tool in promoting best construction practices.
- *Fourth*, integration produces a greater explanatory power than TQM alone in terms of contractors' advancement, and enhances their capacity and performance.

It is posited here that the award dimensions will have different effects on the strategy of development in the construction sector. The King Abdullah II Award for Excellence and the contractor's assessment process encourage the construction industry to continually maintain a good quality management system.

According to findings from several studies, quality management is likely to remain an important corporate strategy in the future (Liu and Kleiner 2001). A corporate culture aimed at TQM and continuous improvement is considered as an important factor that enhances the companies’ capabilities, especially for innovation (Zwetsloot 2001). The model was viewed as being a permissive framework that provided a structured approach to continuous improvement and quality initiatives. As highlighted above, this study has produced interesting findings in promoting best construction quality practices.

CONCLUSION

The model is formulated on the premise that total quality management is the sole technique utilized in construction, and provides a generic framework that can be equally applied to any construction firm regardless of size, sector and structure. The proposed model is drawn to represent an analytical approach that could enable top managers to understand and plan the total quality programs needed in their companies.

The proposed model offers knowledge and skills to local contractors in the disciplines of total quality management. The managers will learn to design effective training that meets the identified gaps in key skill areas and industry sectors. Construction contractors will undoubtedly have to shoulder a major burden of leadership for two reasons: one ideological and the other very practical. Companies will therefore be equipped with the required tools to survive, to face increasing competition and to expand when the time is right. TQM is a desired culture of an organization committed to customer satisfaction. In all cases, however, the criteria mentioned in the model are taking place. The more conscious the contractors are about the requirements mentioned in the model, the better the chances are for their success and the projects. The Ministry of Public Work and Housing has a role in maintaining the quality of construction industry. It must be prepared to cope with the industry's specialized needs and must acquire these capabilities with the aid of educational programmes that take cognizance in TQM.

The results of this research have many implications. The implementation of TQM in construction was expected to promote leadership rather than supervision; intensify the beneficial interaction efforts to participate in work-related decisions; provide a common language in which to operate a comprehensive performance management system that is readily acceptable to technical and managerial staff alike; inspire commitment from the entire organization; to attempt to refine and extend team work; inspire people to seek continuous improvement; and provide a framework for sharing effective practices of construction in its widest sense. This, in turn, can be expected to favourably impact the structures of the construction industry.

It is hoped that this research will provide a foundation and a stimulus for such follow-on efforts. The study should be of value to policy makers, construction managers and construction organizations. Investigating the complete system (as shown in Figure 1) is far too complex an undertaking for one study. Research into the sub-system should be conducted individually and should take into consideration how each sub-system interacts with others. Further research is currently underway, in which it is intended to build up a new approach to assess quality programmes in the construction sector. The proposed system will form the basis of a new model that is specific to construction industry rather than the general models currently used. The King Abdullah II Award for Excellence (KAAE) and the assessment model will create much needed awareness among government and industry leaders about the significance of quality for economic survival and success in today's highly competitive world. The framework results in this study can be very useful as a guide to assessment, planning, and improvements at both the organizational and sectoral level.

REFERENCES

Adebanjo, D (2001) TQM and Business excellence: is there really a conflict? *Measuring Business Excellence*, **5**(3), 37–40.

Al-Momani, A (1995) Construction Practices: The gap between intent and performance. *International Journal of Building Research*, **23**(2).

Al-Momani, A H (2003) Construction delays: a quantitative analysis. *International Journal of Project Management*, **18**, 51–9.

Audi Bank (2003) *Jordan Economic Report*, Bank Audi's Research Department.

Bennet, J, Flanagan, R and Norman, G (1987) *Capital and Counties Report: Japanese Construction Industry*, Centre for Strategic Studies in Construction, University of Reading.

Broetzmann, S M, Kemp, J, Rossano, M and Marwaha, J (1995) Customer satisfaction-lip service or management tool? *Managing Service Quality*, **5**, 13–18.

Brown, S and Eisehardt, K (2000) *Competing on the edge: strategy as a structured chaos*. Boston, MA: Harvard Business School Press.

Cheetham, D W and Carter, D J (1993) The Challenge of Assuring Quality on Site. *Building Research and Information*, **21**(2), 85–98.

Choi, T and Eboch, K (1998) The TQM paradox: relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management*, **17**(1), 59–75.

Dale, B G (1999) *Managing Quality*, 3ed. Oxford: Blackwell.

Easton, G S and Jarrel, S L (1998) The effects of total quality management on corporate performance: an empirical investigation. *Journal of Business*, **71**(2), 253–307.

Export & Finance Bank (2003) *Construction Sector report*, Research and Studies Department.

Fung, P and Wong, A (1995) TQM in construction industry- Hong Kong context. *In: Proceeding of the First International Conference on ISO 9000 and TQM*, De Montfort University, Leicester.

Gil, N, Tommelein, I D, Miles, R S, Ballard, G and Kirkendall, R L (1999) Integrated Product-Process Development Model to Support Design-Build. *To appear in: 2nd Intl. Conference on Concurrent Engineering in Construction- CEC99*, 25–7 August 1999, Espoo, Finland.

Hamel, G (2000) *Leading the revolution*. Boston, MA: Harvard Business School Press.

Hendricks, K B and Singhal, V R (2001) Firm characteristics, total quality management and financial performance. *Journal of Operations Management*, **19**, 269–85.

Henry, E (2000) Quality management standardization in the French construction industry: singularities and internationalization prospects. *Construction Management & Economics*, **18**, 667–77.

Himes, P E (1995) Partnering in the construction process: the method for the 1990s and beyond. *Facilities*, **13**, 13–15.

Jido, J (1996) Quality management with TQM in Takenaka Corporation. *In: Proceedings of International Conference on Quality* (Yokohama).

Jaafari, A (1996) Human Factors in the Australian Construction Industry: Towards Total Quality Management. *Australian Journal of Management*, **21**(2), 159–86.

Jahren, C T and Federle, M O (1999) Implementation of quality improvement for transportation construction administration. *Journal of Management in Engineering*, **15**(6).

Jung, J Y and Wang, Y J (2006) Relationship between TQM and continuous improvement of international project management. *Technovation*, **26**, 716–22.

Kanji, G K and Wong, A (1998) Quality culture in construction industry. *Total Quality Management*, **9**(4&5), S133–S140.

Lahndt, L (1999) TQM Tools for the Construction Industry. *Engineering Management Journal*, **11**(2), 23–27

Leonard, D and McAdam, R (2002) A Strategic Impact and Implementation of TQM. *The TQM Magazine*, **1(**1), 51–60.

Liu, V C and Kleiner, B H (2001) Global trends in managing innovation and quality. *Management Research News*, **24**(3/4), 13–16.

Love, P E D, Li, H, Irani, Z and Faniran, O O (2000) Total quality management and the learning organization: a dialogue for change in construction. *Construction Management & Economics*, **18**(3), 321–31.

McIntyre, C and Kirschenman, M (2000) Survey of TQM in construction industry in upper Midwest. *Journal of Management in Engineering*, **16**(5), 67–70

Milakovich, M E (1995) *Improving Service Quality: Achieving High Performance in the public and private sectors*. Florida: St Luice Press.

Schultzel, H J and Unruh, V P (1996) *Successful Partnering-Fundamentals of Project Owners and Contractors*. New York: John Wiley and Sons.

Serpell, A, de Solminihac, H and Figari, C (2002) Quality in construction: the situation of the Chilean construction industry. *Total Quality Management*, **13**(5), 579–87.

Smith, L J, Jones, I and Vickridge, I (1999) *Increasing Construction Productivity Through Total Loss Control*, UMIST.RICS Research Foundation

Sommerville, J (1994) Multivariate barriers to total quality management within the construction industry. *Total Quality Management*, **5**, 289–98.

Stading, G L and Vokurka, R J (2003) Building quality strategy content using the process from national and international quality awards. *TQM & Business Excellence*, **14**(8), 931–46

Saha, S and Hardie, M (2005) Culture of Quality and the Australian Construction Industry. *In: Proceeding IGLC-13*, July 2005, Sydney, Australia.

Taylor, W A and Wright, G H (2003) A longitudinal study of TQM implementation: factors influencing success and failure. *International Journal of Management Science*, **31**, 97–111.

Tommelein, I D (1999) Toward Integrated Product-Process Development: Research Agenda for Life-Cycle Design and Systems Engineering for the AEC Industry, University of California, Berkeley. Available online: www.ce.berkeley.edu/~tommelein

Walker, D H T and Keniger, M (2002) Quality management in construction; an innovative advance using project alliancing in Australia. *The TQM Magazine,* 307–17.

Wang, A and Fung, P (1999) Total quality management in the construction industry in Hong Kong: A supply chain management perspective. *Total Quality Management*, **10**(2), 199–208.

Xiao, H and Proverbs, D (2002) The performance of contractors in Japan, the UK and the USA: An evaluation of construction quality. *International Journal of Quality & Reliability Management*, **19**(6), 672–87.

Zwetsloot, G (2001) The management of innovation by frontrunner companies in environmental management and health and safety. *Environmental Management and Health*, **12**(2), 207–14.

A STUDY ON QUALITY MANAGEMENT DURING THE PRE-CONSTRUCTION STAGE OF DESIGN-AND-BUILD PROJECTS

Hamzah Abdul-Rahman,[1] Faizul Azli Mohd Rahim, Mohd Suhaimi Mohd Danuri and Low Wai Wah

Center of Project and Facilities Management (PFM), Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia

In the demand for improved procurement methods, the design-and-build approach has become prevalent in the construction industry. However, quality issues in public design-and-build projects raise the alarm for attention. A study was conducted to determine the main inherent quality-related factors, to identify the potential benefits of quality management implementation and to suggest principal quality management methods that can be applied during the pre-construction stage. Data were collected via a questionnaire survey and semi-structured interviews with selected contractors. The interviews served to supplement data received from the questionnaire surveys. The level of management quality among the sample of contractors operating public design-and-build projects was found unsatisfactory. The critical quality-related factors that have contributed to this problem include budget constraints, time constraints, client's complexity, poor communication and design variations. Research findings revealed that the management of time and cost was the most important method in reducing quality-related problems.

Keywords: construction project, design-and-build, procurement, quality management.

INTRODUCTION

The use of the design-and-build procurement method has increased worldwide (Xu and Greenwood 2006). In Malaysia, project delivery methods have changed in the past few decades (Wong 2002a) and design-and-build has become prevalent in the construction industry (Reeves 2002; Kwan 2004). In design-and-build, a contractor takes full responsibility for the whole design and construction process from initial briefing to completion (Chappell *et al*. 2001). Design-and-build is a significant procurement in terms of sustainability (Alnaser and Flanagan 2007; Ugwu and Haupt 2007) and a dominant delivery method (Al-Reshaid and Kartam 2005) in future.

Additionally, quality remains a critical issue in the construction sector (Karim *et al.* 2006). From the contractors' point of view, quality is the cornerstone of competitive strategies to widen and secure clients (Low and Sze 2005). Quality concerns are about the satisfaction of customers' needs, suitability for intended use and performance according to specification (Raj 1988). A quality project can then be defined as a product that meets client requirements specified in the specification.

Quality management is considered as a priority and a potential solution in respect of quality problems. It is defined as the organization structure, responsibilities, activities,

[1] arhamzah@um.edu.my

resources and events appertaining to a firm that together provide organized procedures and methods of implementation to meet quality requirements (BS 5750 1987). Quality management helps to mitigate further consequent quality problems. With effective quality management, quality-related problems can be eliminated and prevented at the early stages (Battikha 2002).

SOME POOR QUALITY SCENES IN CONSTRUCTION

Although the construction industry in Malaysia carries with it many success stories, it is worth noting some areas that often have become challenges and issues to the industry in pursuit of rapid development. According to the Federal Audit Reports 1999–2005 from the National Audit Department of Malaysia, the industry has for many years suffered from quality issues. In the Federal Audit Report 1999, the quality of 23 cases of construction works in seven hospitals did not fulfil the contract specification. The quality of the housing projects, Territorial Army Regiment and Transit Camp, and five Matriculation Colleges suffered serious defects and damages in the Federal Audit Reports 2000–02.

In the Federal Audit Reports of 2003 and 2004 several completed projects were reported to be of unsatisfactory quality. In the Federal Audit Report 2005, the Freshwater Fish Research Centre and the development of new hospital projects did not comply with the specifications and some works sustained serious defects. Among the reported cases, some were constructed based on the design-and-build concept and apparently poor quality in design-and-build projects is not isolated to the Malaysian construction industry.

A BRIEF OVERVIEW OF PREVIOUS RESEARCH SCOPE

Design-and-build studies have varied in scope and focused on different areas. Some (Low and Lim 2000; Chan *et al*. 2001; Ling and Min 2004) looked at the success performance and some (Knight *et al*. 2002; Low and Lim 1999) focused on the failure factors. Work by Ling and Lee (2005) investigated 34 attributes affecting project service quality on design-and-build. The study by Ling (2005) examined the extent of quality achievement and the significance level of 60 quality factors between design-bid-build and design-build. Dulaimi *et al*. (1998) looked at the inherent problems which can influence effective design management. Chan and Yu (2005) stressed contract strategy for design management. Research by Cornick and Barre (1991) studied the quality management aspects and highlighted that design-and-build supports the successful application of quality management to a building.

Such studies highlighted several aspects of academic knowledge gaps. First, there is scarcity of research focused on the quality aspect of design-and-build. Second, there is little academic research on the quality management in design-and-build. Third, there is a need to focus on the pre-construction stage of project development owing to the early involvement of different and multidisciplinary professionals working as a team.

DEBATABLE TIME, COST AND QUALITY ISSUES

Some consider design-and-build projects a success (Akintoye 1994); others consider design-and-build is no better than the traditional procurement system (Retherford 1998; Smith and Wilkins 1996). Studies in Hong Kong indicated that the use of design-and-build provides the benefits of shorter construction time (Tam, 2000) and reduction of cost overruns (Dissanayaka and Kumaraswamy 1999). However, Wong

(2002b) revealed that employers in Malaysia often encounter project cost overruns and delays.

One study found that there is no significant quality advantage with the adoption of the design-and-build method (Akintoye 1994). The negative views of design-and-build included lower quality material and equipment (Abi-Karam 2005), poor design quality (Anumba and Evbuomwan 1997) and failure to fulfil owners' expectations (Yates 1995; Rowlinson 1987). However, some studies reviewed contrasting results and views on quality aspects. Some studies argued that design-and-build projects are able to produce equal or sometimes more desirable quality of work (Lam 1998; Konchar and Sanvido 1998). In fact, a quantitative study uncovered that there is no significant difference in quality between design-bid-build and design-and-build projects (Ling 2005).

QUALITY-RELATED FACTORS

Table 1 presents 18 potential quality-related factors extracted from the literature (Dulaimi *et al*. 1998; Faisol and Adnan 2001; Wong 2002a; Wong 2002b; Knight *et al*. 2002; Ling 2005) and a preliminary survey with a few construction professionals.

Table 1: Quality-related categories

Quality-related categories	Quality-related factors
1. Project-related participants	Client (client's complexity and client's involvement), contractor, design consultants and project manager
2. Project work atmosphere	Effect of traditional procurement, lack of communication, poor relationship and design variation
3. Project characteristic	Novation, time constraint, fast tracking pressure, budget constraints and project complexity
4. Project's information and documentation	Inadequate design, scope and planning, insufficient detail of contractor's tender price and lack of information and documentation management
5. Project management	Poor project management

QUALITY MANAGEMENT IN CONSTRUCTION PROJECTS

Much of the literature confirms that quality management implementation provides tangible benefits to the project parties and the organizations. The identified benefits are:

1. achieving good communication with numerous professionals from entirely different backgrounds in the construction industry (Duncan *et al*. 1990);
2. providing well-documented processes that reduce errors, and provide readily accessible information for employees to acquire knowledge (Bauer *et al*. 2002);
3. improvement of quality awareness (Casadesus and Karapetrovic 2005);
4. improvement of efficiency and effectiveness of plans;
5. improvement of employee morale and exceeding customer requirements (Gitlow 2001).

Several common quality management methods were extracted from the literature (Ashford 1989; Ashworth and Hogg 2002; Chung 1999; Dulaimi *et al*. 1998; Bubshait *et al.* 1999; Gray and Hughes 2001; Law 2004). These included project management contract, contract review, documentation and data control, design management, design control, design review, management review, start-up meetings, constructability planning, time and cost management, build up an effective team and culture change.

RESEARCH AIMS AND OBJECTIVES

The research aims to find out the critical quality-related factors inherent during the pre-construction stage and to recommend appropriate means of managing quality before the start of construction works. The objectives of the study are:

1. to determine the main quality-related factors in public design-and-build projects;
2. to identify the potential benefits through the implementation of an appropriate quality management technique in design-and-build projects; and
3. to examine the principal quality management methods of curtailing quality-related problems in design-and-build contracts.

RESEARCH METHODOLOGY

By reference to the work of Chan and Yu (2005), qualitative and quantitative methods were conducted in the study. The research was limited to government-funded projects.

Quantitative research approach

For the purpose of generalization, a quantitative questionnaire was adopted because of its wide geographic coverage (Naoum 1998). A total sample size of 500 was posted to the contractor firms as sample sizes larger than 30 and less than 500 are appropriate for most research (Roscoe 1975). The names and the addresses of 24 contractors were obtained directly from the Public Works Department (PWD), while the remainder 476 contractors were selected based on random sampling method from the Malaysian Construction Industry Development Board (CIDB) Directory 2005/06 and website.

Contractors were used for the sample as they are responsible for design and construction tasks and carry the most risks. In Malaysia, as the majority of the design-and-build projects were undertaken by higher tender capacity organizations, contractor Grade 7 serves as a better representative population. The focus of the survey was in the state of Selangor and the Federal Territory as they have the highest construction activities and more than 50% of the total contractors' population are found here.

Each respondent was provided with a set of questionnaires and an official letter that contained the research problem statement and research objectives. Questionnaire forms were sent out in mid-December 2005. A one-month period was allowed for the participants to complete the questionnaire. Data were computed in the form of frequency distribution in percentage and mean. A pilot survey was conducted with five professionals having between five and 20 or more years of experience prior to the major fieldwork. The pilot survey aims to test the clarity of the questions by ensuring the questions provide the necessary data to meet the research objectives. Based on the weaknesses specified by the respondents, some questions are either restructured or provided additional explanation (Appendix 1).

Qualitative research approach

To supplement the findings of the structured questionnaire, semi-structured interviews were conducted in February 2006. The study was successfully made up with 10 multidisciplinary professionals, namely project managers, project directors, contract managers, quantity surveyors and engineers. During the interview, interviewees were briefed on the research problem and the research objectives. Interviewees were requested to fill in the questionnaire and to provide additional comments on the issues raised in the questionnaire.

QUESTIONNAIRE FINDINGS

Out of the total 500 sets distributed, 44 usable questionnaires were returned and analysed (8.8% response rate). Respondents comprised six (13.6%) directorate personnel, 28 (63.3%) managerial personnel, six (13.6%) technical personnel and three (4.5%) administrative personnel. The results of the survey were obtained mainly from the managerial personnel with more than 10 years of experience, representing 52.3% (23) of the total respondents.

The use of design-and-build to mitigate time or cost overruns problems

More than half of the respondents provide a positive perception of the use of design-and-build project to mitigate the problems of time or cost overruns where nine (20.5%) respondents strongly agreed and 27 (61.4%) respondents agreed. Six (13.6%) respondents were neutral on this statement and two (4.5%) respondents disagreed that the use of design-and-build projects is able to mitigate the problems of time or cost overruns.

Quality problem between design-and-build and traditional procurements

More than one-third of the total respondents reacted negatively on the use of design-and-build procurement where two (4.5%) respondents strongly agreed and 16 (36.4%) respondents agreed. Another 27.3% (12) of respondents were neutral, 13 (29.5%) respondents disagreed and one (2.3%) respondent strongly disagreed that quality-related problems in design-and-build appear to be more serious than in traditional contracts.

Inherent quality-related factors during the pre-construction stage

Based on the analysis in Figure 1, the five most crucial factors impairing project quality during the pre-construction stage were budget constraints with 86.4% (38), time constraints with 79.5% (35), client's complexity with 72.7% (32), poor communication with 70.5% (31) and design variation with 68.2% (30). In contrast, novation and effect of traditional contract were rated as the least affected quality-related factors with 13.6% (6) and 25.0% (11), respectively.

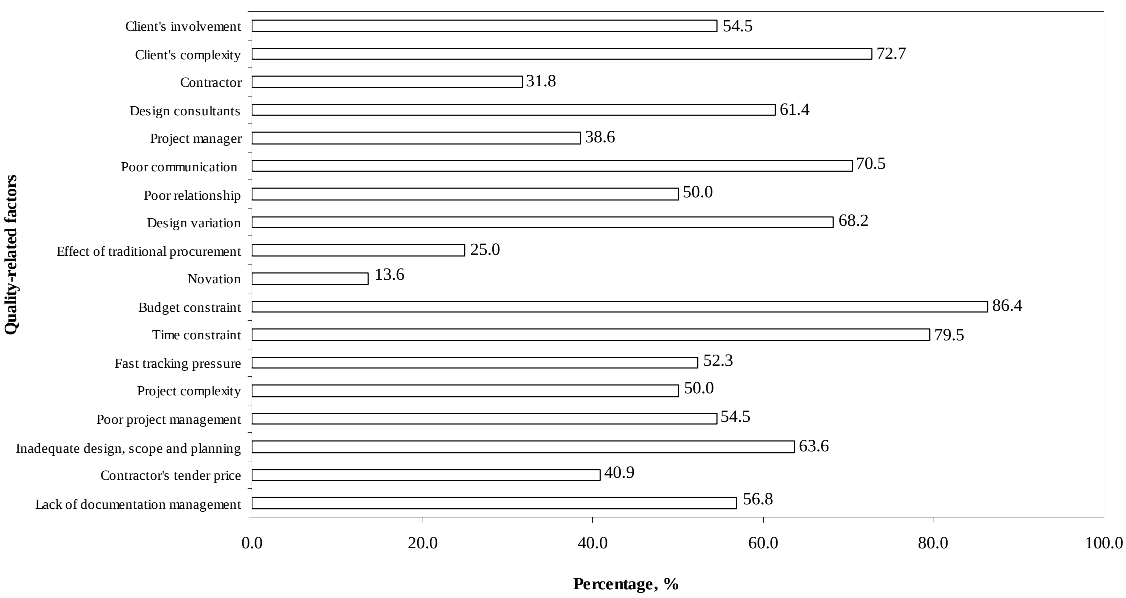


Figure 1: Result data of quality-related factors

Benefits of quality management during the pre-construction stage
Figure 2 shows that all the six benefits achieved responses of more than 50%. The three most significant benefits that would be increased via the implementation of quality management during the pre-construction stage were documentation with 86.4% (38) of total responses, quality awareness with 84.1% (37) of respondents, and achievement of client's requirements and efficiency and effectiveness of plan with 81.8% (36) of total respondents.

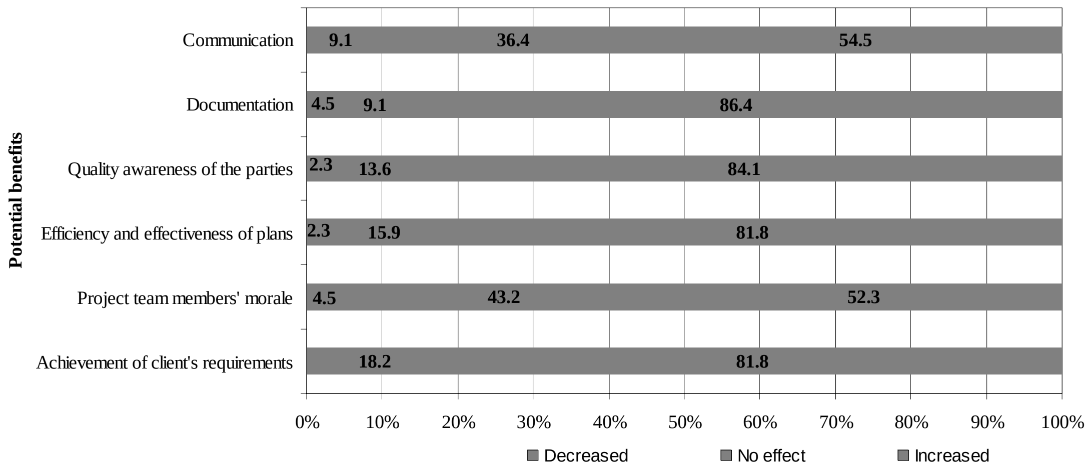


Figure 2: Potential benefits through quality management practice

Quality management methods during the pre-construction stage
Based on the survey results in Figure 3, five critical quality management methods during the pre-construction stage in preventing quality-related problems were time and cost management (4.6), constructability planning and design control (4.4), building an effective team (4.3) and design management (4.2). The least important quality management methods were cultural changes (3.3) and contract review (3.4).

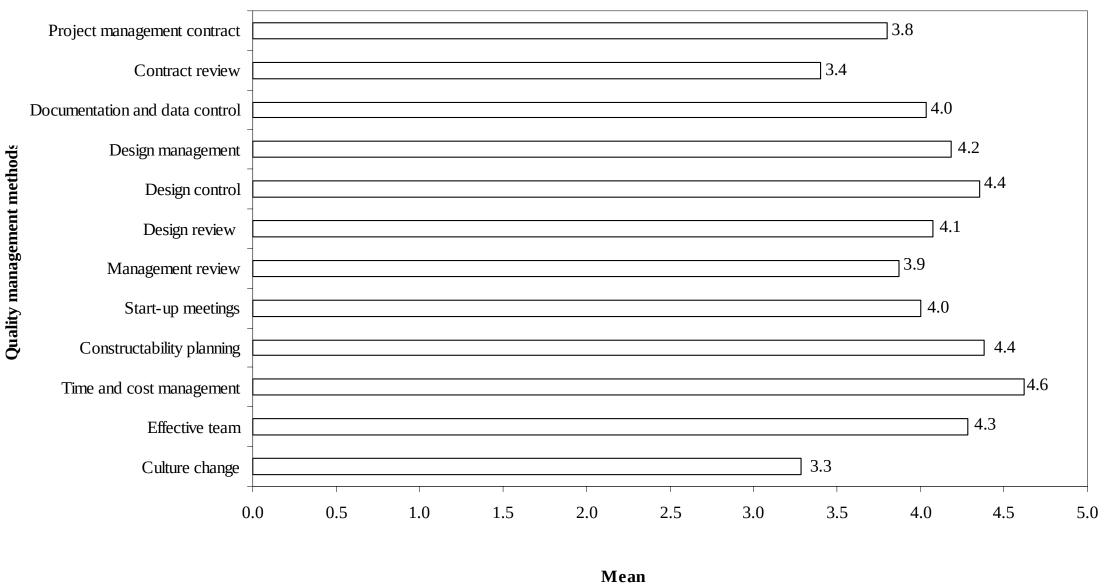


Figure 3: Importance of quality management methods based on mean

SUMMARY OF INTERVIEWS FINDINGS

The use of design-and-build to mitigate time or cost overruns problems

Seven interviewees agreed that involvement of the contractor at the early stage of the project can improve the performance of time and cost aspects. This is because of the improved project constructability and the reduction of design problems during construction. Three interviewees indicated a neutral viewpoint as time and cost aspects depend highly on human factors rather than the type of procurement.

Inherent quality-related factors during the pre-construction stage

Among the inherent quality-related factors during the pre-construction stage were consultants, contractors, project complexity, time constraints and cost constraints. The reasons provided by the interviewees were: (1) contractors have total control over design and construction works; (2) project complexity imposes a higher challenge of foreseeing potential problems at the early stage of the project; (3) the increase of overtime to meet the tight project schedule will influence quality of productivity; and (4) in respect of cost constraints, contractors generally tend to maintain the profit margin rather than quality of the materials. All interviewees disagreed that novation contributes any inherent quality-related problems during the pre-construction stage as novation is seldom practised in this context.

Benefits of quality management during the pre-construction stage

The majority of the interviewees agreed that implementation of quality management at the pre-construction stage provides considerable benefits to the project parties and the final product. Some argued that the benefits of quality management implementation during the pre-construction stage can be fully gained provided project parties strictly implement it throughout the project period.

Quality management methods during the pre-construction stage

The most important quality management methods during the pre-construction stage are design management, design review, start-up meeting, constructability planning, time and cost performance. Nevertheless, causes such as human factors can affect project time and cost performance.

Quality problems in design-and-build and traditional procurements

From the contractors' point of view, quality-related problems appear to be more serious in design-and-build projects than in conventional projects in spite of the fact that the use of design-and-build bridges the gaps between design and construction. The result is supported by Rowlinson (1987) and Akintoye (1994) but is in contrast to Lam (1998). It might be explained that: (1) quality problems mean different things to different people; (2) this may accord with conclusions drawn by Ling (2005): quality problems in design-and-build are not completely due to the procurement system but are also because of other quality-related factors; or (3) construction professionals are more willing or able to commit to time and cost performance rather than quality performance.

Inherent quality-related factors during the pre-construction stage

Budget constraint was the most critical quality-related factor inherent during the pre-construction stage as contractors generally select cheaper designs or hire less experienced labourers to maintain the profit margin. Time constraints pose pressure on the project participants to produce a viable design which can increase the likelihood of design problems during the construction stage and supervision of critical design information. The client's complexity may affect the productivity of the design consultants. More time is required when clients are unsure of the project's needs.

The fourth critical quality factor, lack of proper communication among design and construction project parties tend to break down the integration of project information, skill and knowledge among the project parties. This may lead to the situation where the client's requirements cannot be clearly and fully captured and defined during the pre-construction stage. Design variation is considered as the fifth crucial factor as a change in design will affect the quality of design output and the situation becomes worse if the project schedule is tight and communication between project parties is poor. Findings of the survey discovered that novation is not widely practised in public design-and-build projects, and contractors in practice are flexible to the change in design-and-build projects which pose less impact on project quality.

Benefits of quality management during the pre-construction stage

Findings of the survey evince that implementation of quality management during the pre-construction stage encourages the project parties to fulfil the client's requirements owing to increase in awareness by project parties of the importance of maintaining quality in the project, proper project documentation, and efficiency and effectiveness of plans. The findings are supported by Love *et al*. (2004) as the study found that there was an increase in awareness and focus by all employees and improved staff morale through the initiating of a quality management programme.

Quality management methods during the pre-construction stage

Based on the findings of inherent quality-related factors, the survey findings reflected that time and cost management were the principle means of curtailing quality-related problems during the pre-construction stage. This is because proper managing of time and cost aspects ensures better task coordination, within tasks and across projects which could affect the project quality. Furthermore, proper time and cost management may lead to the proper control of project parties' performance.

Design control is important as it involves controlling of the project design within the client's requirements and ensuring a constructability design is produced before the start of the construction stage. As constructability planning involves the integration of construction and planning knowledge, effective constructability planning helps to identify project barriers and problems before the start of the project. In design-and-build, building up an effective team is an important consideration during the pre-construction stage to ensure that design and construction teams from various disciplines are able to work together and to integrate and accept each other's knowledge.

Research findings showed that design management is closely connected with quality issues. According to Dulaimi *et al*. (1998), effective design management is essential to reduce the perceived problems that can affect the design quality. Thus, practical and comprehensive management is essential during the pre-construction stage.

CONCLUSIONS AND RECOMMENDATIONS

Three major concluding implications are: (1) budget and schedule factors often prevail in public design-and-build projects, which has led to a compromise in quality (this is the area of practice that requires improvement and attention by construction participants); (2) results of quality-related factors and quality management methods form a causes–solutions mirror of pattern which drops a hint to suit the remedy to the crucial quality-related factors; and (3) comprehensive management, teamwork and communication are important elements during the pre-construction stage.

Based on the research findings, several recommendations to the industry include: (1) changes in management attitude, improving the working culture, commitments from clients, contractors and design consultants, are of paramount importance to enhance the value of project quality; (2) government should increase the standard level of quality requirements in project specification; (3) leadership learning and knowledge sharing should be integrated at the early stage of the project; and (4) clients should provide incentives to contractors who able to balance quality, time and cost.

The study is limited in several aspects. The most significant limitation is that the survey findings are based only on the contractors' viewpoints. The response rate of the survey is considered small and unreliable for generalization. Further research can be directed to the private sector to explore quality factors and alternative mechanisms in mitigating quality issues. The research could focus on the construction stage to examine the correlation and the significance of quality factors between the pre-construction and construction stages. Finally, it would be interesting if multiple case studies were used to generate more research data.

ACKNOWLEDGEMENTS

The authors would like to extend thanks to all construction professionals who have participated in this study. A deep sense of gratitude is also extended to those who have in one way or another provided valuable comments to improve the paper.

REFERENCES

Abi-Karam, T (2005) Design/build selection process-art or science? *Cost Engineering*, **47**(5), 14–19.

Akintoye, A (1994) Design and build: a survey of construction contractors' views. *Construction Management and Economics*, **12**(2), 155–63.

Al-Reshaid, K and Kartam, N (2005) Design-build pre-qualification and tendering approach for public projects. *International Journal of Project Management*, **23**(4), 309–20.

Alnaser, N W and Flanagan, R (2007) The need of sustainable buildings construction in the Kingdom of Bahrain. *Building and Environment*, **42**(1), 495–506.

Anumba, C J and Evbuomwan, N F O (1997) Concurrent engineering in design-build projects. *Construction Management and Economics*, **15**(3), 271–81.

Ashford, J L (1989) *The management of quality in construction*. London: E & FN Spon.

Ashworth, A and Hogg, K (2002) *Willis's practice and procedure for the quantity surveyor*. 11ed. London: Blackwell Science Limited.

Battikha, M G (2002) QUALICON: Computer-based system for construction quality management. *Journal of Construction Engineering and Management*, **128**(2), 164–73.

Bauer, J E, Duffy, G L and Westcott, R T (Eds.) (2002) *The quality improvement handbook*. Wisconsin: ASQ Quality Press.

British Standards Institute (BSI) (1987) *British Standard 5750*. Milton Keynes.

Bubshait, A A, Farooq, G, Jannadi, M O and Assaf, S A (1999) Quality practices in design organizations. *Construction Management and Economics*, **17**(6), 799–809.

Casadesus, M and Karapetrovic, S (2005) The erosion of ISO 9000 benefits: a temporal study. *International Journal of Quality and Reliability Management*, **22**(2), 120–36.

Chan, A P C, Ho, D C K and Tam, C M (2001) Design and build project success factors: multivariate analysis. *Journal of Construction Engineering and Management*, **127**(2), 93–100.

Chan, E H W and Yu, A T W (2005) Contract strategy for design management in the design and build system. *International Journal of Project Management*, **23**(8), 630–9.

Chappell, D, Marshall, D, Powell-Smith, V and Cavender, S (2001) *Building contract dictionary*. 3ed. United Kingdom: Blackwell Science Limited.

Chung, H W (1999) *Understanding quality assurance in construction: a practical guide to ISO 9000 for contractors*. London: E & FN Spon.

Cornick, T C and Barre, N J (1991) Quality management and design-build: the opportunities for this method of procurement. *International Journal of Quality and Reliability Management*, **8**(3).

Dissanayaka, S M and Kumaraswamy, M M (1999) Evaluation of factors affecting time and cost performance in Hong Kong building projects. *Engineering, Construction and Architectural Management*, **6**(3), 287–98.

Dulaimi, M F, Morris, G K and Baxendale, T (1998) Design and build projects: the need for effective design management – the UK experience. *The Surveyor*, **33**(1), 44–9.

Duncan, J, Thorpe, B and Sumner, P (1990) *Quality assurance in construction*. Aldershot: Gower.

Faisol, N H and Adnan, H (2001) Factors influencing trends in design and build procurement method. *The Malaysian Surveyor*, **36**(2), 55–64.

Gitlow, H S (2001) *Quality management systems: a practical guide*. Boca Raton, FL: St. Lucie Press.

Gray, C and Hughes, W (2001) *Building design management*. Woburn: Butterworth-Heinemann.

Karim, K, Marosszeky, M and Davis, S (2006) Managing subcontractor supply chain for quality in construction. *Engineering, Construction and Architectural Management*, **13**(1), 27–42.

Knight, A D, Griffith, A and King, A P (2002) Supply side short-circuiting in design and build projects. *Management Decision*, **40**(7), 655–62.

Konchar, M and Sanvido, V (1998) Comparison of US project delivery systems. *Journal of Construction Engineering and Management*, **124**(6), 435–44.

Kwan, F K (2004) Project management – from a design and build contractor's perspective. *Master Builders Journal*, 4th quarter, 78–82.

Lam, S W (1998) Public sector design and build practices. Opening address at the CIDB Design and Build Seminar, April, Singapore.

Law, B J (2004) A preconstruction foundation for design-build success. *In*: *The 48th Annual Meeting of AACE International: 2004 AACE International Transactions*, AACE, Morgantown, PM.18.1–PM.18.3.

Ling, Y Y (2005) Models for predicting quality of building projects. *Engineering, Construction and Architectural Management*, **12**(1), 6–20.

Ling, Y Y and Lee, C K C (2005) Design-and-build contractors' service quality in public projects in Singapore. *Building and Environment*, **40**(6), 815–23.

Ling, Y Y and Min, L (2004) Using neural network to predict performance of design-build projects in Singapore. *Building and Environment*, **39**(10), 1263–74.

Love, P E D, Edwards, D J and Sohal, A (2004) Total quality management in Australian contracting organisations: pre-conditions for successful implementation. *Engineering, Construction and Architectural Management*, **11**(3), 189–98.

Low, S P and Lim, P K O (1999) A case study on why design-and-build fails. *The Malaysian Surveyor*, 34(3), 20-5.

Low, S P and Lim, P K O (2000) Success factors for design-and-build in civil engineering projects: two case study. *Jurutera*, **8**, 57–9.

Low, S P and Sze, H H (2005) Strategic quality management for the construction industry. *The TQM Magazine*, **17**(1), 35–53.

Naoum, S G (1998) *Dissertation research and writing for construction students*. Oxford: Butterworth-Heinemann.

National Audit Department of Malaysia (1999) *Federal Audit Report 1999*. Malaysia.

National Audit Department of Malaysia (2000) *Federal Audit Report 2000*. Malaysia.

National Audit Department of Malaysia (2001) *Federal Audit Report 2001*. Malaysia.

National Audit Department of Malaysia (2002) *Federal Audit Report 2002*. Malaysia.

National Audit Department of Malaysia (2003) *Federal Audit Report 2003*. Malaysia.

National Audit Department of Malaysia (2004) *Federal Audit Report 2004*. Malaysia.

National Audit Department of Malaysia (2005) *Federal Audit Report 2005*. Malaysia.

Raj, R I (1988) Quality management system. *Jurutera*, **9**, 5–8.

Reeves, K (2002) Design and build: where's the contract? *Construction News and Views*, **4**, 5–6.

Retherford, N (1998) Project delivery and the US Department of State. *Journal of Management in Engineering*, **14**(6), 55–8.

Roscoe, J T (1975) *Fundamental research statistics for the behavioral sciences*. New York: Holt, Rinehart and Winston.

Rowlinson, S (1987) *Design build: its development and present status*. Ascot: CIOB.

Smith, A and Wilkins, B (1996) Team relationships and related critical factors in the successful procurement of health care facilities. *Journal of Construction Procurement*, **2**(1), 30–40.

Tam, C M (2000) Design and build on a complicated redevelopment project in Hong Kong: the Happy Valley Racecourse redevelopment. *International Journal of Project Management*, **18**(2), 125–9.

Ugwu, O O and Haupt, T C (2007) Key performance indicators and assessment methods for infrastructure sustainability: a South African construction industry perspective. *Building and Environment*, **42**(2), 665–80.

Wong, J (2002a) Challenges for the quantity surveying profession in the light of new developments. *The Malaysian Surveyor*, **37**(4), 19–21.

Wong, J (2002b) Inherent problems in design and build and its solutions. *The Malaysian Surveyor*, **37**(1), 53–4.

Xu, T and Greenwood, D (2006) Using design-and-build as an entry strategy to the Chinese construction market. *International Journal of Project Management*, **24**(5), 438–45.

Yates, J K (1995) Use of design/build in E/C industry. *Journal of Management in Engineering*, **11**(6), 33–8.

APPENDIX 1: DEFINITION OF TERMS

Inherent quality-related factors during the pre-construction stage

Terms	Definitions
1. Client's involvement	Client involved actively in the project
2. Client's complexity	Many parties represent the clients or clients always unsure of needs
3. Contractor	Inexperienced and irresponsible contractors
4. Design consultants	Inexperienced and irresponsible consultants
5. Project manager	Inexperienced and irresponsible project managers
6. Poor communication	Poor communication between contractors, consultants and clients
7. Poor relationship	Adversarial relationship among project parties due to differences in disciplines and hierarchy authority
8. Design variation	Change of design and drawing
9. Effect of traditional method	So used to traditional procurement
10. Novation	Client's consultants' appointments are transferred to the contractor
11. Budget constraint	Client is too concerned about keeping within the budget
12. Time constraint	Tight project schedule
13. Fast tracking pressure	A project delivery method whereby some portions of construction can begin before the design of other portions is completed
14. Project complexity	Complex in terms of design, size and building components
15. Poor project management	Poor in planning, organizing, leading and controlling
16. Inadequate design, scope and	Insufficient detail design, scope of works and planning

ANALYSING COSTS OF MATERIAL ACQUISITION FOR CONSTRUCTION PROJECTS

Yuan Fang and S. Thomas Ng[1]

Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong.

Materials are important in every construction project as they attribute to a significant proportion of total costs. Because of this, planners and managers should carefully plan and control the ordering, distribution and storage of materials, i.e. the logistic process. Among various available project data, the cost of material acquisition can serve as an indicator to show the efficiency of logistic process. The research devises a material management tool by reference to the acquisition cost. In the proposed model, the delivery of materials is linked to the construction schedule to establish the determinant variables affecting the material acquisition costs *viz*. the delivery cost, storage cost and direct cost of material. Working start time and distribution times are selected as the determinant variables. With GAs (genetic algorithms) tools as simulation method, it is found that just in time delivery and a suitable construction schedule can lead to lower material acquisition costs.

Keywords: construction material, material logistics, acquisition cost, genetic algorithms.

INTRODUCTION

Much attention in construction management research is directed into improving productivity. This is crucial to contractors that strive to maximize their profit and business opportunity. Amongst various factors that could affect construction productivity, resource management is a critical but rather neglected issue. As stated in the European Construction Institute Total Productivity Management Report (ECI 1994), materials delivered to the site are a productivity-related aspect that calls for the introduction of well developed systems to monitor and control their flow. Early and accurate scheduling of materials based on the project schedule and keyed to the master plan for the storage of materials is highly desirable (Enshassi 1996).

Previous studies pointed out that the cost of materials in a typical construction project could be up to 70% of the total cost. Apart from the direct cost, the costs of materials also embrace the logistic cost. In the absence of much room to significantly reduce the direct cost, managers would try to minimize the costs for transporting and storage of resources. The importance of logistic cost has been highlighted in many studies. For instance, an empirical study in Finland (Wegelius 2001) has shown that the total logistic costs for the supply of plasterboard accounted for 27% of its purchase price. Sobotka and Czarnigowska (2005) postulated that any actions towards the rationalization of size, structure and organization of material consumption, along with proper planning of delivery and storage could increase project efficiency.

[1] tstng@hkucc.hku.hk

Despite this, the management of construction materials has seldom been taken seriously by contractors. Approaches for managing and handling materials are rarely examined thoroughly by planners, managers, purchasing teams and estimators at the preliminary project planning stage. Many managers still rely on maintaining excessive buffer stock on site without considering the costs of multi-handling, storage, disruption, damage, wastage, and so on. Besides, the responsibility of various participants and the time in which resource management planning is to be carried out remain vague in many construction projects. Good resource planning should, therefore, focuses on best satisfying the daily resource consumption of a project and cutting down on the unnecessary costs.

In this paper, a material acquisition model is proposed. The model examines the material costs with reference to the project schedule and storage/delivery method so as to support decision-makers in making material planning decisions. Genetic algorithms (GAs) are used for model development due to its simplicity, robustness and ability to handle various functional representation problems, such as those with very complex inter-functional and intra-functional relationship (Lam *et al*. 2001). The paper begins with a brief introduction of the material management practice. The mechanism of the proposed material acquisition model is highlighted. Finally, a case example is used to illustrate the concept of the proposed model.

MATERIAL MANAGEMENT PRACTICE

To avoid workers and plant staying idle, most construction projects tend to keep a certain amount of stock on site. This may inevitably increase delivery and inventory costs due to multiple handling and storage. As the storage space on site is limited, sometimes an intermediate warehouse may be set up by the contractor nearby for the temporary storage of larger construction components. This may further lengthen the communication channel and delivery process. For these reasons, it may be desirable to apply a Just-In-Time (JIT) concept. Using JIT means materials are delivered directly from supplier’s warehouse to the site JIT to the request. Akintoye (1995) suggested that the JIT philosophy could be applied for logistics management on worksites to raise the productivity levels. A study in Denmark reported a 10% rise in productivity in housing projects when JIT was adopted (Bertelsen 1995).

A modified system consists of both on-site storage and external supply components as shown in Figure 1 is proposed. While less bulky materials are stored on site, larger construction components shall be kept at suppliers’ warehouse. In Figure 1, the construction process consists of activities *w*1, *w*2 and *w*3 with a different start dates, and each activity will necessitate certain resources to complete. Assuming that three resources (i.e. C1, C2 and C3) are needed for the project, the manager shall refer to the sequence of activities and their start dates before initiating an order.

Upon receiving the request, the purchasing team would review the amount of stock on site before the order is placed such that the storage, transportation and purchasing cost can be minimized. For bulky items, the manager will review the progress of work and liaise with the supplier to determine the exact date and time for material delivery. Therefore, the manager must maintain good communication with the purchase team and suppliers to keep them updated on the progress and resource needed.

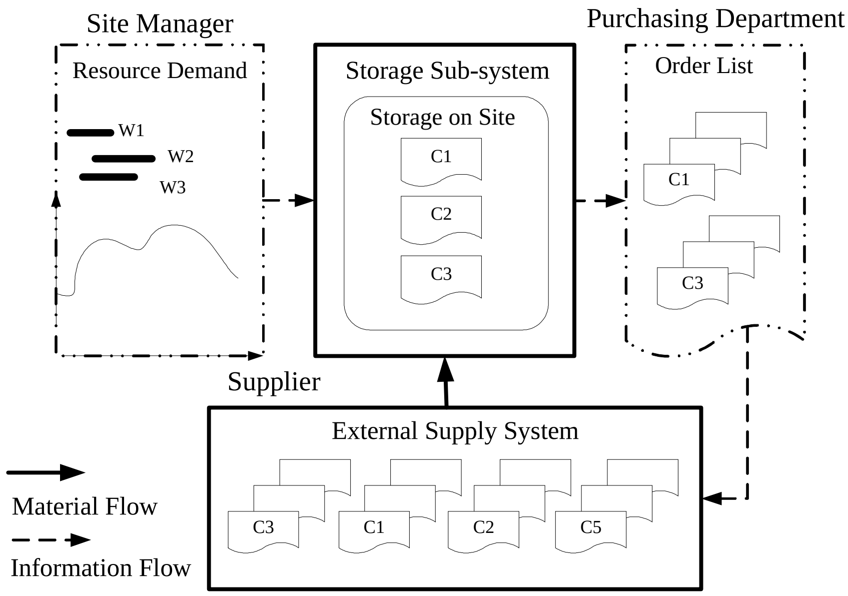


Figure 1: Material acquisition model

MATERIAL ACQUISITION COST FUNCTIONS

Based on the modified system, the following assumptions are derived for subsequent model simulation.

1. The total quantities of resource consumption can be determined when an order is placed. The purchasing team can place an order approximate to the total quantities of materials needed.
2. As the supply contract should have been signed and the terms agreed, it is not necessary to consider the discount rate at this stage.
3. The cost for ordering is considered minimal and is therefore ignored.
4. The quantity of distribution quantity is the same each time, while the frequency of delivery is determined by $q_1 = q_2 = ... = q_i = ... + q_n = \frac{\sum_{j=1}^{D} R}{n}$, in which R is the daily resource consumption.
5. The delivery interval is separated by the delivery times equally.

The most basic form of the material acquisition function is represented by Equation 1:

$$K = K_L + K_D \quad (1)$$

where K represents the total material acquisition costs; K_L and K_D are the logistic costs and direct costs respectively.

The direct cost (K_D) is computed by:

$$K_D = c_j \cdot \sum_{i=1}^{n} q_i \quad (2)$$

where c_j is the unit price of material j; q_i is the quantity of delivery i; and n signifies the total number of delivery.

The logistic costs (K_L) include the cost of transportation from the supplier's warehouse to site (K_T); cost of capital being frozen as a result of the inventory (K_C); cost of penalty on material shortage (K_P); and cost of storage on site (K_S).

$$K_L = K_T + K_C + K_P + K_S \tag{3}$$

$$K_T = k_{et} \cdot n \tag{4}$$

where k_{et} represents the cost of external transport per delivery.

$$K_C = c_j \cdot p \cdot \sum_{i=1}^{D} s_s \tag{5}$$

where p denotes the cost of capital being frozen for the inventory per number per day; D is the number of days; and s_s is the volume of inventory on the building site per day.

$$K_P = \sum_{i=1}^{D} p_d \cdot S_i \tag{6}$$

where p_d is the penalty for each item of material in shortage; and S_i is the number of material shortages on i day.

$$K_S = C_s \sum_{i=1}^{D} s_s \tag{7}$$

where C_s is the inventory cost in building site per day.

The above equations describe the optimization problem on the basis of a period of time. The optimization of logistic processes, however, is a dynamic succession of daily optimization problems, which will be treated independently, even though they are not. The one-day problem solution sets the initial conditions of the problem for the next day. Therefore, different solutions for the same daily problem originate a different scheduling problem for the coming day. Here, the performance of the system is analysed by considering a longer time units, such as weeks, months or the whole project period.

IMPACTING VARIABLES

The cost functions capture the relationship between the costs of material acquisition and certain variables. In the cost functions, some parameters – like the cost of external transportation per delivery and the cost of maintaining an inventory, and so on – may remain unchanged. However, some could vary and any changes of such variables will affect the total cost.

Material consumption variable (x_1)

One of the variables affecting material consumption is the start time of an activity (T_{is}) as it must satisfy the following:

$$T_{iES} \le T_{is} \le T_{iLS} \tag{8}$$

$$\max\{T_{js} + t_j\} \le T_{is} \tag{9}$$

where T_{iES} is the activity's earliest start time; T_{iLS} is the activity's latest start time; T_{js} represents all the start times preceding an activity; and t_j is the activity duration.

Although this variable does not appear in the cost functions, different activity start times will lead to different resource demands and, hence, different order schedules. The change of x_1 will result in different K. As Equations 8 and 9 require the activity to begin before the latest start time but after the earliest start time, an activity cannot begin until all the preceding activities are accomplished. The difference between T_{iLS} and T_{iES} is the flexible time FT. The activity can begin at anytime during this period. A suitable activity start time will give a perfect resource consumption curve, which will result in the lowest cost.

Distribution variables (x_2)

The distribution variable concerns the number of distribution (n) from suppliers' warehouses to the site, i.e. $0 < n \leq D$.

This variable decides how many distributions will be made by the suppliers. The purchasing team must decide the best timing to supply the materials to site in order to avoid overstock or materials shortage from occurring. Any material bottlenecks will lead to construction delays and induce extra costs. Yet, an overstock will in turn increase the storage fee and frozen capital and both will affect the profit.

GENETIC ALGORITHMS

Genetic algorithm (GA) technique is used for model development. GAs originate from computer simulation research in biology systems. Through the inspiration of biological simulation techniques, Professor Holland and his students in Michigan University developed a self-adaptation optimization technology based on genetic and evolution concepts (Holland 1975; Goldberg 1989). GAs perform the three genetic operations –selection, crossover and mutation – on a population of individuals (i.e. genes). A solution to a given problem is represented in the form of a string called a 'chromosome', which consists of a set of genes holding a set of values for the optimization variables (Gloderg 1989). The fittest individuals in the environment (optimization problem) will have a higher chance to survive for mating (crossover). The new population will replace the ones that did not survive. Therefore, the new generation ought to be fitter than its parents are and with less chance of dying. This process continues until a sufficient fitness is achieved (Silva *et al*. 2005)

For GA programming, there are three main aspects to be considered. The first is the coding method, and a suitable representation of the solutions in form of a chromosome should be established. For the material acquisition cost simulation, the variables of x_1, x_2 can be defined as the chromosomes. The initial populations of these variables are generated randomly. The second issue to be considered is the fitness function. This function determines how well an individual is fitted to the environment. In this paper, the material cost functions are used as fitness function. The last aspect is the operations. Each of the three operations (i.e. selection, crossover and mutation) can be performed in various ways; this has been the subject of extensive studies in the last decade, as the way in which the operations are executed can influence the efficiency of the algorithm significantly. Therefore, many parameters such as the size of the population, crossover and mutation rate, etc., have to be determined.

RESULTS AND DISCUSSIONS

Using a project schedule with eight construction activities (Sun 2004) as shown in Table 1, the unit price of material c_j is 2.55; the cost of frozen capital for inventory p is 0.24; the penalty for each item of material shortage p_d is 10; the cost of external transportation per delivery is 250; and the daily cost of site storage C_s is 5 per item (Sobotka and Czarnigowska 2005).

Table 1: Working schedule

Work	Duration	Work Earliest Start Time (T_{iES})	Work Latest Start Time (T_{iLS})	Flexible Time (*FT*)	Resource Consumption Per Day (*R*/*D*)
A	8	0	0	0	600
B	10	0	8	8	300
C	10	8	8	0	500
D	11	8	23	15	400
E	17	8	17	9	300
F	16	18	18	0	700
G	9	19	34	16	600
H	9	34	34	0	400

According to Table 1, $\sum_{i=1}^{n} q_i = \sum_{d=1}^{43} R = 42{,}500$. The variables in this model are activity start time (x_1) and number of times for delivery (x_2). The activity start times of activities B, D, E and G are considered as variables because they have flexible time. Here, x_1 is an integer matrix, where $T_{iES} \leq x_{1i} \leq T_{iLS}$; and $x_{12} \in (0{,}8]$, $x_{14} \in (8{,}23]$, $x_{15} \in (8{,}17]$, $x_{17} \in (19{,}34]$. Besides, x_2 is an integer, where $0 < x_2 \leq D$; $x_2 \in (0{,}43]$.

Here, 40 individuals and 30 generations were set for the simulation. The individuals get closer to an optimal result as the generations evolve. The simulation results of the minimal cost and population average cost for each generation are shown in Table 2.

Table 2: Minimal cost and population average cost of each generation

Generation	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Minimal Cost (1.0e+006)	0.4422	0.4706	0.4385	0.4043	0.2813	0.2813	0.2813	0.2464
Average cost (1.0e+006)	1.3123	1.3244	0.7976	0.9779	0.9492	0.7671	1.0451	0.7120
Generation	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
Minimal Cost (1.0e+006)	0.2464	0.2464	0.2632	0.2632	0.2632	0.2424	0.2464	0.2464
Average cost (1.0e+006)	0.7306	0.6618	0.7792	0.7889	0.6076	0.6902	0.6686	0.5401
Generation	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
Minimal Cost (1.0e+006)	0.2173	0.2173	0.2173	0.2173	0.2173	0.2173	0.2173	0.2173
Average cost (1.0e+006)	0.5356	0.5814	0.6934	0.5071	0.4777	0.4922	0.6172	0.5717
Generation	*25*	*26*	*27*	*28*	*29*	*30*		
Minimal Cost (1.0e+006)	0.2173	0.2173	0.2173	0.2173	0.2173	0.2173		
Average cost (1.0e+006)	0.5340	0.4018	0.4305	0.3550	0.5260	0.4780		

According to Table 2, the minimal cost decreases as the generation times increase. At the 17th generation, the minimal cost becomes stabilized. The population average cost for each generation is also in a decreasing trend, although there are still mutations occasionally. The minimal material acquisition cost is \$21,730 and the variables for this result is (x_{12},x_{14},x_{15},x_{17},x_2) = (1,9,13,32,41). This implies that when activities B, D, E and G begin onthe 1st, 9th 13th and 32nd days respectively, and the material distribution is based on the daily delivery until the 41st day, the material acquisition cost will be the least. The material to be delivered to site is 1,037 items per day.

Figure 2: Resource consumption and storage

Figure 2 shows the daily resource consumption and daily storage when $(x_{12},x_{14},x_{15},x_{17},x_2) = (1,9,13,32,41)$. As shown, there are still some shortages from dates 19-27, 34 and 35. This is due to an excessive requirement of materials during these periods, notwithstanding the adjustment of the start date for the activities. In other words, such a high material requirement cannot be avoided by simply adjusting the activity start date. Since the optimal delivery quantity and interval is based on the minimal material acquisition cost, the purchasing team can increase the size of delivery size during those periods that are likely to have material shortage.

CONCLUSIONS

In the construction industry, careful planning of construction materials plays an important part in increasing productivity. As the materials costs contribute to a large proportion of the total construction costs, good resource planning can benefit a project having time and cost constraints. In this paper, a material acquisition model is set up and the related cost functions are highlighted. The model aims to optimize the material acquisition cost. The simulation is carried out in Gas to help identify the relationships amongst the cost, delivery method and project schedule.

This study can be seen as an initial step towards an integrated construction logistic modelling and simulation. The resource acquisition model in the paper is based on the JIT concept where no off-site warehouse is used. The outcomes of this paper form a basis for further research. Further research will focus on resource planning of systems with an intermediate warehouse, systems with more than one construction project, etc. The assumptions in this study can also be modified according to the modelling situation.

REFERENCES

Agapiou, A, Clausen, LE, Flanagan, R, Norman, G and Notman, D (1998) The role of logistics in the materials flow control process. *Construction Management and Economics*, **16**(2), 131–7.

Akintoye, A (1995) Just-in-time application and implementation for building materials management. *Construction Management and Economic*, **13**, 105–32.

Bertelsen, S (1995) *Building logistics: a means for improvement of productivity in the building sector*. Nellemann, Nielsen& Rauschenberger A/S Consulting Engineering and Planners, Denmark.

Bishop, D (1965) *Operational bills and cost communication*. Current Paper Design Series 55, Building Research Station, Garston.

ECI (1994) *Total productivity management: guidelines for the construction phase*. European Construction Institute Loughborough, Leics.

Enshassi, A (1996) Materials control and waste on building sites. *Building Research and Information*, **24**(1), 31–4.

Glodberg, DE (1989) *Genetic algorithms in search, optimization and machine learning*. Reading, MA: Addison-Wesley Publishing Co.

Holland, J H (1975) *Adaptation in natural and artificial systems*. Ann Arbor, MI: University of Michigan Press.

Kasperek, M and Lewtak, W (2004) *Analysis of logistic processes impact on execution cost of construction project*, MSc thesis, Politechnika Lubelska, 2004 (in Polish).

Lam, K C, Hu, T S, Ng, S T, Yuen, R K K, Lo, S M and Wong, T C (2001) Using an adaptive genetic algorithm to improve construction finance decisions. *Engineering, Construction and Architectural Management*, **8**(1), 31–45

Silva, C A, Sousa, J M C, Runkler, T and Palm, R (2005) Soft computing optimization methods applied to logistic processes. *International Journal of Approximate Reasoning*, **40**, 280–301.

Sobotka A and Czarnigowska A (2005) Analysis of supply system models for planning construction project logistics. *Journal of Civil Engineering and Management*, **6**,73–82.

Sun Mingtao and Cao Qingkui (2004) Based on genetic algorithm supply chain corporation order scheme optimization. *Journal of Hebei Institute of Architectural Science and Technology*, **21**(2).

Wegelius-Lehtonen, T (2001) Performance measurement in construction logistics. *International Journal of Production Economics*, **69**, 107–16.

DEFINING THE LEAN AND AGILE CHARACTERISTICS OF ENGINEER-TO-ORDER CONSTRUCTION PROJECTS

Jonathan Gosling,[1] Mohamed Naim,[1] Andrew Fearne[2] and Nicholas Fowler[3]

[1]*Innovative Manufacturing Research Centre, Cardiff Business School, Cardiff University, Cardiff CF10 3EU, UK*
[2]*Centre for Supply Chain Research, University of Kent, Canterbury CT2 7PE, UK*
[3]*Denne Construction, Sittingbourne, Kent ME9 8FH, UK*

Lean and agile supply chain strategies for high volume manufacturing with standardized products and a repetitive environment have been well explored. In contrast, there is a lack of research into low volume engineer-to-order (ETO) products in contexts such as construction. The purpose of this paper is to examine characteristics of the lean and agile paradigms and explore their relative importance to ETO construction projects. It helps to overcome the confusion regarding 'is lean appropriate for a construction supply chain?'. This is a conceptual study developing definitions and models for ETO supply chains by synthesizing of available literature. Characteristics of lean and agile paradigms are reviewed and mapped against the ETO structure. The classification developed makes the case that construction-related ETO supply chains have far more in common with the agile characteristics.

Keywords: agile construction, lean construction, supply chain management.

INTRODUCTION

Two paradigms that have received a significant amount of attention in supply chain management are lean thinking and agile manufacturing. The term 'lean construction' has been coined to describe applications of lean thinking in construction and has received a lot of attention from both academics (Howell 1999; Koskela 1992) and UK government initiatives (Egan 1998). Agility has also been proposed as a possible strategy in construction, but it has received much less attention (Barlow 1998; Naim and Barlow 2003).

Some of the recent literature questions the extent to which lean thinking is a universal strategy that can be applied in all contexts (Christopher and Towill 2002; Cooney 2002; James-Moore and Gibbons 1997; Naylor *et al*. 1999). Similarly, the applicability of lean thinking in a construction environment is being questioned (Barlow 1998; Thomas *et al*. 2002). This paper aims, first, to define the context of construction projects relative to other supply chain structures and, secondly, it sets out the possible lean and agile strategic choices for such construction projects. A fundamental question answered in this paper is 'are lean and agile strategies appropriate for engineer-to-order construction projects?'.

This paper is conceptual, based on a synthesis of academic literature on lean and agile operations and supply chain structures. In the next section the construction

[1] goslingj@cardiff.ac.uk

environment is characterized as an engineer-to-order supply chain and is compared with other supply chain structures. Then, the key differences highlighted in the lean thinking and agile manufacturing literature are described. Finally, the ETO classification is mapped against the characteristics of lean and agile strategies to examine possible applications.

THE ENGINEER-TO-ORDER SUPPLY CHAIN STRUCTURE

A range of supply chain structures have been proposed to illustrate the diverse range of supply chain operations. Based on Hoekstra and Romme (1992), Naylor *et al*. (1999), Yang and Burns (2003), Olhagar (2003) and Lampel and Mintzberg (1996) six different supply chain structures can be defined: engineer-to-order (ETO), buy-to-order (BTO), make-to-order (MTO), assemble-to-order (ATO), make-to-stock (MTS) and ship-to-stock (STS). Based on the aforementioned authors, Figure 1 shows the level of standardization and customization that takes place before a customer order is received in each of the different supply chain structures. The line that runs through the different structures shows the point at which the customer order enters the supply chain. The customer, in this case, is taken to be the next direct receiver of the material in the supply chain as opposed to the ultimate end user.

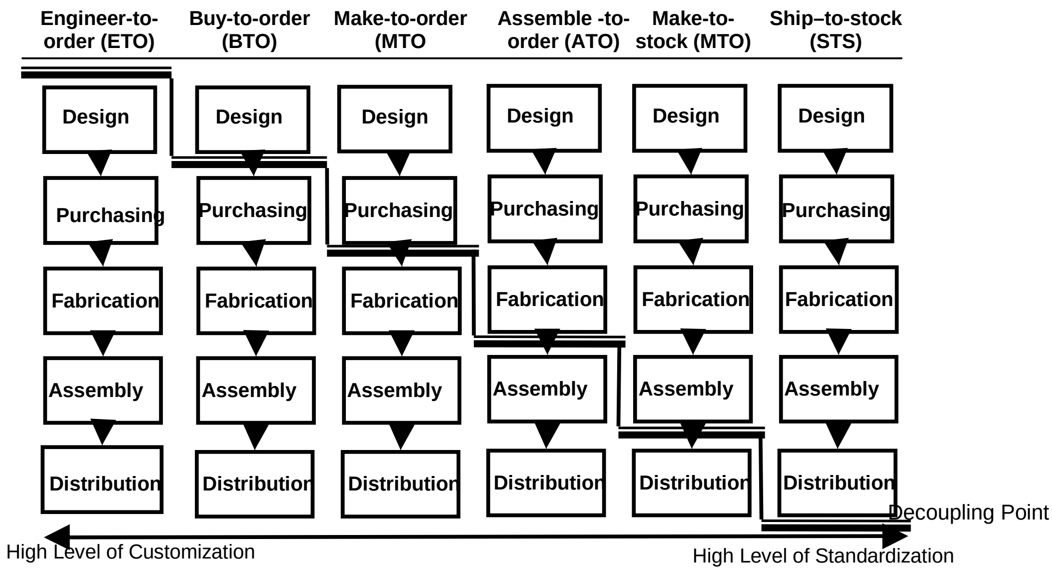


Figure 1: The six different supply chain structures (synthesis from various sources)

In order to add clarity to the ETO supply chain structure, a literature review was conducted on ETO products and supply chain structures. Differences between supply chain structures were identified through this literature review and were subsequently synthesized into a number of dimensions that can be used to differentiate between different structures. Table 1 summarizes the main differences between the supply chain structures. These have been categorized as inputs and outputs, with inputs illustrating the strategic enablers and outputs showing the outcomes visible to the customer. The following descriptions highlight some of the key characteristics by reference to the extremes of the spectrum and to intermediate structures as appropriate.

Core competences

Each of the supply chains described has a core competence. The ETO structure has a core competence of delivering highly customized products to meet an individual customer order. A BTO structure is able to deliver customized products that have diverse raw materials and components and the MTO excels at delivering customized products that have common raw materials and components. An ATO supply chain structure has a core competence in delivering cost effective mass customization. MTS and STS environments, on the other hand, excel at managing standardized, high volume products to either a pre-defined central outlet or local outlets while offering low cost and instant availability (Amaro *et al*. 1999; Naylor *et al*. 1999).

Table 1: Attributes of different supply chain structures (synthesis from various sources)

Attributes	**Engineer-to-order (ETO)**	**Buy-to-order (BTO)**	**Make-to-order (MTO)**	**Assemble-to-order (ATO)**	**Make-to-stock (MTS)**	**Ship-to-stock (STS)**
Outputs						
Customization	Extremely high	Very high	High	Moderate	Low	Very low
Time to market	Extremely high	Very high	High	Moderate	Low	Very low
Volume	Extremely low	Very low	Low	Moderate	High	Very high
Complexity	Extremely high	Very high	High	Moderate	Low	Very low
Inputs						
Decoupling point	Design	Purchasing	Fabrication	Assembly	Distribution – central	Distribution – local
Purchasing	Identify sources of supply	Schedule product deliveries from suppliers	Hold raw materials/ components	Fabricate or buy modules	Hold finished goods centrally	Hold finished goods locally
Stocks	No stock	No stock	Raw materials	Pre-assembled modules	Finished goods	Finished goods
Design	Produce new design	Modify existing design	Pick from wide range of options	Pick from limited range of design options	Take design as is	Take design as is
Method	Project/job shop	Job shop	Batch	Batch/Flow	Flow	Flow
Forecasting	Extremely low	Very low	Low	Moderate	High	Very high

Level of customization

Offering customization to the market is increasingly becoming recognized as a source of strategic advantage (Lampel and Mintzberg 1996; Pine 1993; Salvador *et al.* 2001). This recognition of the strategic importance of satisfying true customer demand has been reflected in the supply chain literature, where market-driven supply chains have received much attention (Childerhouse 2002). The ability to fully customize according to the needs of an individual customer is a central feature of the ETO supply chain (Amaro *et al.* 1999). In other supply chain structures the levels of customization offered to the customer are lower. In the ATO structure customization is delivered through mass customization. Choice for the customer would be offered in the form of standardized options and would be configured to order from stock of 'modules' (Naylor *et al.* 1999). In a MTS or STS supply chain the customer has little scope for customization and would have to take a standard product 'off the shelf'.

Time to market

The time to market for a product has also been used to categorize supply chains and manufacturing operations (Fisher 1997; Olhager 2003). The production to delivery time ratio (P/D ratio) is often quoted as a method to make decisions about time to market. If the production lead time is greater than the desired maximum customer delivery time that is acceptable to the customer (P/D ratio is greater than 1) then a produce to stock, that is, either MTS or STS structure is more appropriate. If the production lead time is lower than the desired maximum customer delivery time that is acceptable to the customer (P/D ratio is lower than 1) then a supply chain does not necessarily need to produce to stock (Olhager 2003).

In an ETO structure, a customer is often exposed to the total supply chain, which can include design, procurement, manufacture, assembly, testing and commissioning of a product, so the time to market can be extremely high. However, it is likely that the customer will be prepared to wait longer for a fully customized product and may agree to a due date at a negotiated cost at the design stage (Amaro *et al.* 1999). The more a supply chain resembles a STS structure the quicker a customer can be satisfied.

Production volume

Product mix and volume have long been key classifications for production and supply chain operations (Olhager 2003; Salavador 2002). High and low volume supply chains pose different challenges to operations. When compared with high volume supply chains, low volumes often pose problems in terms of power regimes and uncertainty in the volumes of components required (Hicks 2000). ETO products are generally characterized as high variety and extremely low volume, possibly ‘one-off’ builds, whereas MTS products are often produced in large volumes (Cameron *et al.* 2004). The more a supply chain resembles a STS structure the higher the production volume will tend to be.

Product complexity

The complexity of a product will have a bearing on the supply chain structure that is employed (Hicks *et al.* 2000). Product complexity refers to the depth of the product structure, the amount of sub-assemblies and the amount of components that form the product. An ETO product will often have a deep product structure, complex sub-assemblies and many components. Consequently, the supply networks for complex products tend to be broad upstream, whereas less complex products tend to be dominated by fewer players (Cameron *et al.* 2004; Hicks *et al.* 2001). In contrast, a STS structure is likely to be suitable for a product with a shallow product structure. The ATO and MTO structures are likely to have moderate depth of product structure with careful thought given to modularity, product architecture and management of product variety (Salvador *et al.* 2002; Boothroyd *et al.* 1994; Pine 1994).

The decoupling point

The customer order decoupling point (CODP) is a stock holding point that separates the part of the supply chain that responds directly to the customer from the part of the supply chain that uses forecast planning. The decoupling point can act as a strategic buffer against the variability in demand and an efficient way of scheduling standardized parts. Upstream from the CODP all products are produced to forecast; downstream from the CODP all products are pulled by the end user (Hoekstra and Romme 1992; Naylor *et al.* 1999; Christopher 2000; Olhager 2003; Mason-Jones *et al.* 2000). Figure 1 shows the decoupling point for the six different supply chain structures. As an example of its application let us consider three of the strategies. The decoupling point in the ETO supply chain lies at the design stage. The customer order asserts a high level of customization for all activities in the supply chain. Distribution, assembly, fabrication, purchasing and design are all customized according to customer order. The decoupling point in the STS supply chain is the local distribution channel; here there is no customization whatsoever.

Purchasing and stocks

The position of the decoupling point, described above, has a significant impact on the purchasing and strategic stockholding. Suppliers in an ETO structure are identified and mobilized in response to a specific customer order and would, typically, service a particular project. An ETO product may put every order out to competitive tender to a group of potential suppliers with the correct capabilities (Amaro *et al.* 1999; Hicks *et al.* 2000). Stock will then be purchased according to the needs of a specific project. In a BTO structure the supply chain is established but no stocks are purchased. Product deliveries are scheduled from established suppliers after an order has been received. At the other end of the spectrum, the STS structure holds finished goods from established suppliers at a local distribution channel in order to satisfy forecasted demand very quickly.

Design

The level of influence that a customer has in the design process has significant implications for the supply chain. For example, design for production and assembly techniques, such as modularity, simplified product architecture, carefully revised product commonalities and interfaces, have been promoted as methods of reducing costs and supporting mass customization (Boothroyd *et al.* 1994). Based on Amaro *et al.* (1999), the degree of design customization can be categorized along five different classifications: produce new design; modify an existing design; pick from a wide range of design options; pick from a limited range of design options; and take existing design as is. An ETO project will require a new design with a large amount of customer input, whereas a MTS or STS supply chain, for example, designs for a general market based on recommendations by marketing departments (Rahman *et al.* 2003). Designs will show increasing levels of standardization and reduced direct customer input the further a supply chain moves away from the ETO structure. In a BTO supply chain similar existing designs are modified to new customer requirements whereas the MTO and ATO mass customization strategies are used to offer degrees of standardized options.

Production method

The production method refers to the technique used to manufacture or assemble a product. Four popular assembly methods are job shops, batching, flow and project. The technique used will vary depending on the complexity and volume of the product (Hicks *et al.* 2000; Ballard 1998; Porter *et al.* 1999). The production method for an ETO supply chain will incline towards a project or job shop assembly method. Project production offers a unique product, requiring large-scale inputs to be coordinated so as to achieve customers' requirements. Various projects may be 'live' at any one time, resulting in a multi-project environment (Porter *et al.* 1999). A STS structure is more likely to involve flow production. Flow production is characterized by the large volume production of a small range of standard products (Porter *et al.* 1999). An ATO structure may involve a mixture of batch and flow production, with flow being utilized upstream from the CODP and batch utilized downstream from the decoupling point.

Level of forecasting

The ease with which demand for a product can be forecasted has also been widely used to classify different supply chains (Fisher 1997; Naylor *et al.* 1999; Olhager 2003). The level of forecasting is closely related to demand volatility and the level of customization. In supply chains where demand volatility and customization is high the potential for forecast error usually increases. Supply chains that have more stable demand characteristics and standardized products can usually forecast demand more accurately.

The level of forecasting possible in an ETO supply chain structure is extremely low in relation to other structures. The high degree of customization and low volumes involved result in high levels of uncertainty and lumpy demand patterns. Any stock runs the risk of becoming obsolete and incorrect to specification. When products are more standardized and volumes are higher, such as in the MTS and STS structures, the level of forecasting possible increases, as it is possible to forecast aggregate demand more accurately. ETO companies often have to forecast skills, capacities and industry trends, whereas MTS companies are required to forecast the type of product, quantity and location (Rahman *et al.* 2003).

DIFFERENTIATING LEAN AND AGILE SUPPLY CHAIN STRATEGIES

Since the advent of agility (Iacocca Institute 1991) an academic debate has taken place to distinguish lean and agile philosophies and their applicability (Naylor *et al.* 1999; Christopher and Towill 2000; Hines *et al.* 2004; Van Hoek 2000; Vonderembse *et al.* 2006). Some have stated that lean is a prerequisite for agile supply (Goldman *et al.* 1995; Narasimhan *et al.* 2006); others have argued that lean is an overall umbrella of which agility is part (Papadopoulou *et al.* 2005). The aim here is to identify the principal strategic differences between the lean and agile paradigms at the supply chain level. An extensive literature review was conducted to highlight the strategic differences. Table 2 summarizes the key differentiators of lean and agile strategies. Naylor *et al.* (1999) offer useful definitions to summarize the differences between these paradigms, which have been widely adopted by, among others, Christopher and Towill (2002) and Narasimhan *et al.* (2006). Leanness means developing a value stream to eliminate all waste, including time, and to ensure a level schedule. Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place.

Table 2: Differentiating lean and agile strategies (synthesis from various sources)

Differentiator	Lean	Agile
Outputs		
Market winner	Cost	Service level
Performance characteristics	Cost efficiency	Delivery and flexibility
Product variety	Suitable for low variety	Suitable for high variety
Variability	Suitable for low variability	Suitable for high variability
Inputs		
Responding to the market	Confirmed orders/smooth demand/level scheduling	Respond quickly to market changes
Forecasting method	Algorithmic	Consultative
Supply chain relationships	Close relationship with a small number of suppliers	Virtual/extended enterprise
Sourcing decisions	Cost and quality	Speed, flexibility and quality
Approach to waste	Reduce the 7 wastes	Focus on service level, not eliminating waste
Capacity	Smooth capacity	Hold spare capacity
Time compression	Remove NVA and shorten as long as it does not increase cost	Invest aggressively to reduce lead times

Market winner

Classifications have been developed to highlight that lean and agile strategies differ in their suitability for different markets. The application of market winners and qualifiers has been used widely to distinguish markets for lean and agile strategies. If service level is the market winner with cost, quality and lead time as the market qualifiers, then agility is more appropriate. If cost is the market winner and quality, service level and lead time are the market qualifiers, then leanness is more suitable (Mason-Jones *et al.* 2000; Naylor *et al.* 1999).

Performance characteristics

Empirical studies have attempted to highlight the performance characteristics of lean and agile supply chains (Narasimhan *et al.* 2006; Power *et al.* 2001; Sharp *et al.* 1999). Cost efficiency is a primary performance outcome associated with lean thinking whereas agile supply chains demonstrate superior abilities in terms of delivery and flexibility (Narasimhan *et al.* 2006). More agile companies have been found to be more customer focused than less agile companies (Power *et al.* 2001) and agile supply chains have also been found to have developed abilities to continuously change (Sharp *et al.* 1999).

Product variety and variability

Product variety and volume are frequently alluded to in the lean and agile literature. Variety and variability have both been offered as a basis for selecting lean or agile strategies. High variety and high variability is commonly associated with the application of agility and low variety and low variability with the application of leanness (Christopher 2000). Much of the literature suggests that a feature of the agile supply chain is flexibility with regard to product lines and variants. An agile supply chain responds accurately to markets through customization (Christopher 2000; Yusuf *et al.* 1999). The agile supply chain also excels at shifting capacity to meet sporadic changes in demand, which is particularly desirable in volatile markets (Yusuf *et al.* 2003).

A focal point of the criticism of lean supply chains has been their inability to cope with variability. In order to add value to the customer the lean approach seeks to find ways to manage variability by flattening or controlling demand (Naylor *et al.* 1999; Hines *et al.* 2004). It has been noted that in high value, low volume industries the implementations of leanness are scarce. This is due to the high degree of customization, inherent complexity of the process routings, diverse processing times and high product mix. It is also difficult to map the flow and level production in such environments (Papadopoulou *et al.* 2004). Agility excels in fast moving volatile markets that place a premium on shifting quickly in terms of product lines and product volume; leanness excels in markets with stable demand and standardized product lines (Christopher 2000; Mason-Jones *et al.* 2000; Naylor *et al.* 1999).

Responding to the market

A key differentiator between lean and agile approaches is the response to the market and uncertainty. Should a supply chain focus its energies on stabilizing uncertainty or becoming flexible in order to take advantage of market changes? A lean agenda seeks to drive out fluctuations by smoothing demand and achieving a level schedule. The lean enterprise seeks to deliver value through careful consideration of the cost–value proposition (Hines *et al.* 2004; Naylor *et al.* 1999; Papadopoulou *et al.* 2005). A key attribute underpinning agility is a capability to reconfigure in a way that responds quickly to the variations and disturbances in the marketplace (Christopher 2000; Naylor *et al.* 1999; Sharp *et al.* 1999; Yusuf *et al.* 1999). To be truly agile a supply chain must be market sensitive, with capabilities in reading and responding to real time demand and routine and painless adaptation (Yusuf *et al.* 1999).

Forecasting method

The forecasting method used for lean and agile supply chains can also be distinguished. Demand in an agile supply chain may be met by 'intelligent' consultation and through developing abilities in becoming market sensitive (Christopher 2000; Mason-Jones *et al.* 2000). This consultation approach places an increased significance on the need to distribute real time data throughout the supply chain (Christopher 2000; Power *et al.* 2001; Yusuf *et al.* 1999). Demand in a lean supply chain is much more likely to be met by forecasting (Mason-Jones *et al.* 2000).

Supply chain relationships

There are differences in the lean and agile literature on how supply chain relationships should be treated and managed. Lean thinking reinforces the need for close supplier relations, a reduced supply base organized under a tier system. Supplier associations, systems integrators and exchange of personnel are documented as examples of lean commitment to relationship building. At the centre of this type of collaboration is transparency, jointly defined value, joint analysis of waste and working together to allow a smooth flow of material through the supply chain. It emphasizes joint commitment to reducing waste and continuous improvement (Hines 1994; Womack and Jones 1996).

The literature on agility suggests the virtual or extended enterprise as a key part of the agile supply chain (Christopher 2000; Yusuf *et al.* 1999; Goldman *et al.* 1994; Gunasekaran 1999; Sharp *et al.* 1999). A critical mass of organizations with diverse core capabilities that can be combined to satisfy different customers is necessary. The virtual supply chain aims to pull together resources and skills that can quickly respond to individual needs and have been described as 'fluid clusters' of suppliers or project teams that come together to meet a particular need or opportunity (Mason-Jones *et al.* 2000). Virtual enterprises are temporary and represent a fundamental source of flexibility for the agile supply chain (Gunasekaran 1999). Competencies and resources are held in the form of a virtual or extended enterprise in order to reconfigure and respond quickly in terms of expertise, skills, materials and extra capacity (Yusuf *et al.* 2003). The approach to choosing suppliers may also reflect a lean or agile agenda. In a lean supply chain, suppliers with competencies in low cost and high quality will be required, whereas agility calls for suppliers who can demonstrate speed, flexibility and quality (Vonderembse *et al.* 2006).

Approach to waste and capacity

Leanness calls for the elimination of all waste. In particular, the seven wastes of over-production, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary movement, defects have been widely quoted (Womack *et al.*. 1990). In a 'pure' lean supply chain there would be no slack. In an agile supply chain, where there is a focus on service level, spare capacity may be reserved and stock needs to be carefully considered to meet rapid changes in end user requirements (Naylor *et al.* 1999; Christopher and Towill 2000; Yusuf *et al.* 1999). A lean supply chain advocates standardized flows of material according to just-in-time principles and close integration of supply chain partners. Internal production flows can be stabilized by Kanban systems and continuous improvement initiatives incrementally drive out forms of waste. An agile supply chain also seeks to drive out waste but not at the expense of speed and flexibility. Strategic stock points (or decoupling points) may be used to reduce the time of finished goods to the marketplace and spare capacity may be held to deal with fluctuations in demand.

Time compression

Time compression plays a crucial role in both lean and agile philosophies. The importance of time compression for agility has been well documented (Mason-Jones *et al.* 1999; Towill 2003; Yusuf 1999). Lean thinking also promotes the reduction and elimination of non-value-adding time and classifies it as a waste (Womack and Jones 1996). The difference in the approach to time compression is that lean thinking aims to shorten lead time as long as it does not increase costs; an agile supply chain may seek to aggressively invest in ways to reduce lead times even if it incurs a cost but maximizes service to the customer (Vonderembse *et al.* 2006).

MATCHING LEAN AND AGILE CHARACTERISTICS TO ENGINEER-TO-ORDER PROJECTS

An important assertion in this paper is that the majority of construction projects have much in common with the ETO supply chain. The scope of construction is diverse, but many projects will reflect the majority of the ETO supply chain structure attributes set out in Table 1. Previous classifications have argued that increasing levels of leanness are appropriate in the STS structure and increasing levels of agility are appropriate moving through the supply chain structures towards the BTO (Mason-Jones *et al.* 2000; Naylor *et al.* 1999). Using the classifications outlined in the previous sections of this paper, Table 3 shows the proposed relationships between the attributes of the ETO structure and the characteristics of agility, which have not previously been researched. Some key themes that emerge from matching characteristics of leanness and agility into the ETO project environment are now discussed.

Responding quickly to market changes

Owing to the strategic outputs of an ETO supply chain (see Table 3), responding to the market becomes a premium. This supports the application of an agile strategy. A supply chain can either attempt to become more responsive or can manage the demand flow. Developing flexibility and market sensitivity, in the case of the ETO supply chain, appears to be of greater importance than developing stability and efficiency. The responsiveness of an ETO supply chain will depend, largely, on the network of collaborative firms and suppliers based on core competencies to meet the market demand in good time. Sourcing decisions in an ETO should be biased towards speed, flexibility and quality rather than purely cost considerations. The agile ETO supply chain responds to customization requirements and sudden demand swings by holding extra capacity in the form of the virtual/extended enterprise and by placing the decoupling point at the design stage.

Managing customization, variety and variability

Ability to manage product variety and variability is crucial for construction enterprises. A possible strategy to manage the diverse product variety in construction is to ‘forward shift’ through supply chain structures via modularity. A firm can seek to forward or backward shift through supply chain structures for strategic benefit. A forward shift may help to reduce the delivery lead time to customers and increase manufacturing efficiency while a backwards shift may help to increase the knowledge of customer orders at the time of production (Olhager 2003). In the house-building and commercial sector there have been moves to forward shift through the supply chain structures by adopting modular design and greater standardization of supply chain activities (Barlow *et al.* 2003; Voordijk *et al.* 2006). This kind of modularity moves construction away from the ETO structure towards the assemble-to-order structure and helps to combine aspects of leanness and agility. In the manufacturing literature this combination has been termed 'leagility' (Naylor *et al.* 1999).

Invest aggressively to reduce time to market

The time to market in the ETO construction projects is often extremely high. Previous research highlights the importance of lead time reduction in the ETO environment. Late changes in design and competitive bidding have been suggested as major contributors to long lead times in ETO projects (Elfving *et al.* 2005). Concurrent engineering techniques, performance measures and business process re-engineering have been suggested as strategies to compress time (Gunasekaran 1999; Towill 2003).

Table 3: Relationships between the ETO supply chain structure and agile characteristics

Attributes of engineer-to-order supply chains structure	Proposed relationships to agile characteristics
Outputs	
Highly customized products to meet an individual customer order	• Responding quickly to the market (input) • Focus on service level, not eliminating waste (input)
Extremely high level of customization	• High variety (output) • High variability (output) • Hold spare capacity (input)
Extremely high time to market	• Invest aggressively to reduce lead times (input) • Respond quickly to the market (input)
Extremely low production volume	• High variability (output)
Extremely high product complexity	• High variety (output)
Inputs	
Decoupling point at the design stage	• Product variety (output) • Responding to the market (input)
Identify sources of supply to order	• Virtual/extended enterprise (input) • Sourcing decisions based on speed, flexibility and quality (input) • Hold spare capacity (input)
No stock	• Delivery and flexibility as desired performance characteristics (output)
Produce new design for each order	• Product variety (output) • Responding to the market (input)
Project/job shop method	• High variety (output) • Hold spare capacity (input)
Extremely low level of forecasting	• Consultative forecasting method (input)

CONCLUSIONS

This is, primarily, a conceptual study developing definitions and models for ETO supply chains. This paper provides models and constructs as a basis to think about agility in the ETO sector. The literature on supply chain structures has been reviewed and the attributes of six supply chain structures have been described. This paper has shown that construction has much in common with the ETO supply chain structure. Literature on lean and agile strategies has also been synthesized to develop a table of differentiators to distinguish lean and agile strategies. Strategic characteristics of agility have been mapped against attributes of ETO supply chains to develop frameworks and definitions for the agile ETO supply chain. The research question addressed in this paper was 'are lean and agile strategies appropriate for engineer-to-order construction projects?'.

This paper highlights that there is much overlap between the attributes of the ETO structure and the characteristics of agility. Our observations are that the supply chain structure classification is a superior framework for considering strategies, as the relationships and concepts surrounding leanness, agility and other best practice models are difficult to disentangle. The classifications in this paper allow construction enterprises to assess the most appropriate strategies for their projects and the implications are that organizations working in the ETO sector need the strategic characteristics of agility. Further research is required to determine the application of these classifications; this will to be undertaken via detailed case studies.

REFERENCES

Amaro, G, Hendry, L and Kingsman, B (1999) Competitive advantage, customisation and a new taxonomy for non-make-to-stock companies. *International Journal of Operations and Production Management*, **19**(4), 349–71.

Ballard, G and Howell, G (1998) What kind of production is construction? Paper presented at IGLC-6, 13–15 August 1998, Guaruja, Brazil.

Barlow, J (1998) From craft production to mass customisation? Customer-focused approaches to house-building. Paper presented at IGLC-6, 13–15 August 1998, Guaruja, Brazil.

Barlow, J, Childerhouse, P, Gann, D, Hong-Minh, S, Naim, M and Ozaki, R (2004) Choice and delivery in housebuilding: lessons from Japan for UK housebuilders. *Building Research & Information*, **31**(2), 134–45.

Boothroyd, G, Dewhurst, P and Knight, W (1994) *Product design for manufacture and assembly*. New York: Marcel Dekker Inc.

Cameron, N S and Braiden, P M (2004) Using business process re-engineering for the development of production efficiency in companies making engineered to order products. *International Journal of Production Economics*, **89**(3), 261–73.

Childerhouse, P (2002) *Enabling seamless market-orientated supply chains*, Unpublished PhD Thesis, Logistics Systems Dynamics Group, Cardiff University.

Christopher, M (2000) The agile supply chain: competing in volatile markets. *Industrial Marketing Management*, **29**(1), 37–44.

Christopher, M and Towill, D R (2000) Supply chain migration from lean and functional to agile and customised. *International Journal of Supply Chain Management*, **5**(4), 206–13.

Christopher, M and Towill, D R (2002) Developing market specific supply chain strategies. *International Journal of Logistics Management*, **13**(1), 1–14.

Cooney, R (2002) Is lean a universal production system? Batch production in the automotive industry. *International Journal of Operations and Production Management*, **22**(10), 1130–47.

Egan, J (1998) *Rethinking construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions. London: HMSO.

Elfving, J A, Tommelein, I D and Ballard, G (2005) Consequences of competitive bidding in project-based production. *Journal of Purchasing and Supply Management*, **11**, 173–81.

Fisher, L M (1997) What is the right supply chain for your product? *Harvard Business Review*, March/April, 105–16.

Goldman, S L, Nagel, R N and Preiss, K (1995) *Agile competitors and virtual organizations: strategies for enriching the customer.* New York: Van Nostrand Reinhold.

Gunasekaran, A (1999) Agile manufacturing: a framework for research and development. *International Journal of Production Economics*, **62**, 87–105.

Gunasekaran, A and Ngai, E W T (2005) Build-to-order supply chain management: a literature review and framework for development. *Journal of Operations Management*, **23**(5), 423–51.

Hicks, C, McGovern, T and Earl, C F (2000) Supply chain management: a strategic issue in engineer to order manufacturing. *International Journal of Production Economics*, **65**, 179–90.

Hicks, C, McGovern, T and Earl, C F (2001) A typology of engineer-to-order companies. *International Journal of Logistics: Research and Applications*, **4**(1), 43–56.

Hines, P (1994) *Creating world class suppliers.* London: Pitmans.

Hines, P, Holweg, M and Rich, N (2004) Learning to evolve – a review of contemporary lean thinking. *International Journal of Operations and Production Management*, **24**(10), 994–1011.

Hoekstra, S and Romme, J (1992) *Integral logistics structures: developing customer oriented goods flow*. London: McGraw-Hill.

Howell, G A (1999) What is lean construction? *IGLC*-7, California, 1–10.

Iacocca Institute (1991) *21st century manufacturing enterprise strategy*, Report for Lehigh University, Bethlehem, PA.

James-Moore, S M R and Gibbons, A (1997) Is lean manufacture universally relevant? An investigative methodology. *International Journal of Operations and Production Management*, **17**(9), 89–911.

Koskela, L (1992) *Application of the new production philosophy to construction*, Technical Report No. 72, CIFE, Stanford University, Stanford, CA.

Lampel, J and Mintzberg, H (1996) Customizing customisation. *Sloan Management Review*, **38**(1), 21–30.

Mason-Jones, R, Naylor, J B and Towill, D (2000) Engineering the leagile supply chain. *International Journal of Agile Management Systems*, **2**(1), 54–61.

Naim, M M and Barlow, J (2003) An innovative supply chain strategy for customised housing. *Construction Management and Economics*, **21**, 593–602.

Narasimhan, R, Swink, M and Soo Woo, K (2006) Disentangling leanness and agility: an empirical investigation. *Journal of Operations Management*, **24**, 440–57

Naylor, J B, Naim, M M and Berry, D (1999) Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics*, **62**, 107–18.

Olhager, J (2003) Strategic positioning of the order penetration point. *International Journal of Production Economics*, **85**(3), 319–29.

Papadopoulou, T C and Özbayrak, M (2005) Leanness: experiences from the journey to date. *Journal of Manufacturing Technology*, **16**(7), 784–807.

Pine B (1993) *Mass customisation: the new frontier in business competition*. Boston: Harvard Business School Press.

Porter, K, Little, D, Matthew, P and Rollins, R (1999) Manufacturing classifications: relationships with production control systems. *Integrated Manufacturing Systems*, **10**(4), 189–98.

Power, D J, Sohal, A S and Rahman, S U (2001) Critical success factors in agile supply chain management: an empirical study. *International Journal of Physical Distribution & Logistics Management*, **31**(4), 247–65.

Rahman, A, Rahim, A, Shariff, M and Baksh, N (2003) The need for a new product development framework for engineer to-order products. *European Journal of Innovation Management*, **6**(3), 182–96.

Salvador, F, Forza, C and Rungtusanatham, M (2002) Modularity, product variety, production volume, and component sourcing: theorizing beyond generic prescriptions. *Journal of Operations Management*, **20**(5), 549–75.

Sharp, J M, Irani, Z and Desai, S (1999) Working towards agile manufacturing in the UK industry. *International Journal of Production Economics*, **62**(1), 155–69.

Thomas, H R, Horman, M J, De Souza, U E L and Zavriski, I (2002) Reducing variability to improve performance as a lean construction principle. *Journal of Construction Engineering Management*, **128**(2), 144–54.

Towill, D R (2003) Construction and the time compression paradigm. *Construction Management and Economics*, **21**, 581–91.

Van Hoek, R I (2000) The thesis of leagility revisited. *International Journal of Agile Management Systems*, **2**(3), 196–201.

Vonderembse, M, Uppal, M, Huang, S and Dismukes, J (2006) Designing supply chains: towards theory development. *International Journal of Production Economics*, **100**(2), 223–38.

Voordijk, H, Meijboom, B and de Haan, J (2006) Modularity in supply chains: a multiple case study in the construction industry. *International journal of Operations and Production Management*, **26**(6), 600–18.

Womack, J P and Jones, D T (1996) *Lean thinking*. New York: Simon & Schuster.

Yusuf, Y Y, Sarhadi, M and Gunesekaran, A (1999) Agile manufacturing: the drivers, concepts and attributes. *International Journal of Production Economics*, **62**(1–2), 33–43.

Yusuf, Y Y, Adeleye, E O and Sivayoganathan, K (2003) Volume flexibility: the agile manufacturing conundrum. *Management Decision*, **41**(7), 613–6.

TOWARDS BRIDGING THE 'FINANCING GAP' IN CONSTRUCTION FIRMS IN GHANA WITH SPECIAL REFERENCE TO CAPITAL EQUIPMENT ACQUISITION FINANCE

M.D. Owusu,[1] E. Badu,[1] D.J. Edwards[2] and T. Adjei-Kumi[1]

[1]*Department of Building Technology, Kwame Nkrumah University of Science Technology, Kumasi, Ghana Private Mail Bag Kumasi-Ghana*
[2]*Department of Civil and Building Engineering, CBE, Loughborough University, UK*

This empirical research conducted in Ghana validates and demonstrates the existence of a financing gap between financial institutions and contractors in relation to capital equipment acquisition. The results show that the demand for finance from contractors is far in excess of the supply from lending banks. Several interrelated factors account for this gap. The survey found that there was a strong desire to establish a contractors' specialized lending bank to feed the local construction industry. The factor analysis performed placed significant emphasis on the establishment of a conducive legal framework and formulation of effective lending policies within which lenders and borrowers can operate. There would be the need for further research to explore the possibilities of exploiting the credit bureau system in Ghana since information asymmetry was crucial in the financing gap.

Keywords: factor analysis, financing gap, lending system, loanable fund.

INTRODUCTION

The financing gap has rigorously been challenged in literature in the context of cross-country, cross-economic sectors and cross-organizational domain as a measure of financing requirements for the 'necessary' investment in the short and long run and provides the basis for the determination of financing shortfalls (Ray and Hutchinson 1983; Taylor 1994). Galizia and Steinberger (2001) identified the financing gap as the difference between the capital formation and the savings of the corporate sector. Easterly (1999) confirmed the earlier proposition of Taylor by concluding that the financing gap is a temporal gap between investment ability and savings ability of classical organizations in which this gap is in a form of aid when viewed from cross-country perspectives.

In generic terms, the financing gap defines the difference between the demand and supply of external finance by corporations over a given period and measures the need for external funds. An explanation was advanced for this measure, thus: for a given level of capital formation, whatever funds the corporate sector cannot generate from internal sources (retained earnings or cash flow), these have to be advanced from other sources

[1] degraft2000@yahoo.com

(thus, through the banking sector, non-banking financial sector, trade credit, etc.). These funds come typically in a form of credit facilities from statutory financial institutions, coupled with high demands from construction corporations with acute shortage in supply (Galizia 2003). Available literature and empirical data confirmed that the aggregate demand of finance exceeds the aggregate supply. Easterly (1999) attested that there exists a financing gap in the lending systems of financial institutions regarding provision of finance to firms of varying degrees of capitalization within and across different sectors of the economy. This observation was consistent with the findings from the Macmillan Committee of Inquiry into Finance and Industry of the UK (Macmillan Report 1931); the Federal Reserve System of the USA (1958); and the Radcliff Committee of the UK (1959). Later, Bates (1960) and Stole and Curley (1970) challenged the previous findings by stating that firms' financing gap does not exist in the United States and the United Kingdom in the sense that short- and long-term finance and equity capital are available to those who prove their creditworthiness.

While some researchers identified financing gaps, others were of the view that there are no such gaps. The conflicting evidence and analogous mismatches are attributed to the approach and criteria adopted by various researchers to define or measure the financing gap. Unfortunately, it is hard to find research work in developing countries, like Ghana, to support the above discourse.

The primary goal of the paper is to advance knowledge and validate whether there is a financing gap in the lending system of Ghana regarding construction funding with special emphasis on capital-equipment acquisition finance; and identify potential strategies to bridge those gaps if any.

THE STRUCTURE OF GHANAIAN CONSTRUCTION INDUSTRY: THE PAST AND THE PRESENT

The government of Ghana, as in many countries, is the major underwriter of the construction industry and exercises its control through two construction ministries (Eyiah and Cook 2003). The Ministry of Water Resources, Works and Housing (MWrWH) formerly Ministry of Works and Housing (MWH) is responsible for housing infrastructure while the Ministry of Transportation (MT) formerly Ministry of Road and Transport (MRT) is responsible for roads and civil-related infrastructures (Ghana Highway Authority 2004).

Agencies supporting these ministries include the Ghana Highway Authority (GHA) responsible for trunk roads connecting 13 400km of the national capital to the regional capitals, from regional capitals to district capitals and towns within the regions (inter-regions and districts), the Department of Feeder Roads (DFR) responsible for feeder roads connecting 32 000km of the rural communities to the trunk road network, production centres and markets with the Department of Urban Roads (DUR) that also connects 3700km roads within the seven (7) metropolitan and municipal areas (Ghana Highway Authority 2002).

In addition to the requirement by law for companies operating in Ghana to register with the registrar general, construction firms that wish to undertake public projects are required to register with the appropriate construction ministry. After registration, contractors are classified into various categories depending on the type of work they wish to undertake. The MWrWH classifies contractors into categories D and K, while the MRT classifies contractors into categories A, B, C and S (Eyiah and Cook 2003). Contractors in each category are further grouped into financial classes 1, 2, 3 and 4 based on their technical and managerial expertise, financial standing, previous performance, and equipment and plant holding. The minimum requirement for qualification into each class and category is provided in guidelines by the ministries. Contractors can register with any of the ministries, and then be grouped into one or more of the categories and their respective classes. For example, a contractor can be classified as A1–A4, B1–B4 and D1–D4 and K1–K4. An attempt to state the number of contractors in the country and in each category would be misleading in that both ministries do not have an up-to-date list of contractors operating within their sectors. The difficulty in doing so emanates from the easy entry and exit to the industry.

Fortunately, the Association of Building and Civil Contractors Ghana (ABCCG) has a comprehensive list of paid-up members of those in the financial class 1 category. While many individuals consider the industry to be a lucrative sector, others leave, without notification, due to the inherent problems. The contractors association has existed in Ghana since pre-independence. The Ghana Contractors Association, as it was called, was renamed the Civil Engineering and Building Contractors Association of Ghana (CEBCAG) in 1985. Membership of the association is open to any company registered as civil engineering or building contractors with the MRT and MWrWH. Conflicts of interest resulted in the spilt of the association into the Association of Road Contractors and the Building Contractors Association. Consultancy services in Ghana are provided by several agencies and organizations including the Building and Road Research Institute (BRRI), Architectural and Engineering Services Limited (AESL), and several private sector consulting firms with professional institutional memberships. The main professional bodies controlling professional conduct in the industry are Ghana Institution of Surveyors (GhIS), Ghana Institution of Engineers (GhIE) and Ghana Institution of Architects (GIA).

SOURCES OF EXTERNAL FINANCE FOR THE CONSTRUCTION SECTOR IN GHANA

The formal capital market, mainly banks, leasing firms and other financial intermediaries, is the main possible source of obtaining external funds for contractors in Ghana (Bank of Ghana 2000). Unfortunately, the informal capital market in Ghana operates in almost total obscurity. Very little is known about its size, scope and the types of individuals that provide it. Studies of the informal capital market are virtually non-existent in Ghana and it is safe to say that policy makers and academics know almost nothing about the characteristics of this market, except that it is likely to be a large and important market for private firms to raise equity capital (Aryeetey *et al*. 1994). Of course, there are good reasons for this obscurity, thus the informal capital market involves transactions in private equity securities not subject to the rigorous disclosure requirements for public equities, and there is almost no institutional infrastructure supporting the market. In addition, the market appears to be highly localized and segmented. Currently, the formal capital market of Ghana where contractors raise debt finance consists of the Bank of

Ghana as the central bank controlling and supervising the activities of 18 different clearing banks (deposit banks) categorized as: (1) commercial banks; (2) development banks; (3) investment banks; and (4) merchant banks holding universal licence with minimum equity base of ¢70 billion – equivalent to US$7.6million (Bank of Ghana 2006). There is also an apex institution known as ARB Apex bank licensed by the Bank of Ghana to oversee the operations of 117 rural banks licensed as unit banks in the country.

Other financial institutions such as money market financial institutions (i.e. discount houses) complement the operations of the banks. Similarly, there are also non-bank financial institutions comprising (1) building societies; (2) savings and loans companies; (3) finance houses; (4) leasing and hire-purchase companies; and (5) venture capital funding brokerage firms (Bank of Ghana 2006). In addition, there is a stock exchange, which provides the platform for secondary dealings in equities of listed companies with no construction firm listed on the stock market. The other group of institutions operating within the financial system is the insurance companies, which are licensed and regulated by the National Insurance Commission (NIC).

EQUIPMENT ACQUISITION FINANCE STRATEGY: THEORETICAL AND EMPIRICAL EVIDENCE FROM GHANAIAN CONTRACTORS' PERSPECTIVES

The following sections are based on the actual questionnaire responses from contractors and the outcome of the in-depth interviews with senior executives of leading leasing firms and financial institutions in Ghana. A construction contractor wishing to acquire capital equipment for the execution of a particular project or possible business expansion in Ghana is presented with a wide range of choices by which the financing of the acquisition can be accommodated (Edwards *et al*. 1998). Despite the apparent flexibility of the profiles, the choice will essentially come down to one form of financing; thus loan or credit facility to offset the purchase, hire purchase, rentals and/or leasing arrangement, etc. (Viswanath 1999).

According to Edwards *et al*. (1998) the financial benefits alone may show there is little to choose between the competing forms of finance when tax benefits available to both the financier and the customer are taken into account. However, the legal distinctions between these financing arrangements are essential, affecting the issues of ownership, security, title, balance sheet reporting, etc. (Viswanath 1999). In most developed countries such as the UK, USA and Germany, favourable tax and accounting rules have had a significant influence on the development of the capital equipment financing industry (Edwards *et al.* 1998). The empirical results consistent with theoretical arguments suggest that construction firms in Ghana mainly utilized unallocated profit or equity capital, debt finance (via short-term borrowing) and instalment debt (via leasing and hire purchase arrangements). Many studies suggested that equipment acquisition finance via instalment debt or term financing plan (leasing) has become an important financing alternative the world over. Over the years, this form of capital asset finance has played a significant role in the economic development of most developed countries through the provision of much needed capital assets for productive businesses. The high incidence rate of equity capital compared to other forms of long-term leverage for equipment acquisition revealed by studies in Ghana is an indication of the underdeveloped state of long-term leveraging in the industry. But this is still too problematic for most companies having low annual profits to purchase major production means considering the relatively high capital intensiveness involved in equipment acquisition. Bank credit is hardly achievable for many construction companies because of the shortage of long-term credit, that is, credit for a period of over one year. Leasing arrangements provide for a fixed interest rate on the credit. Very few or no banks in Ghana possess financial resources to be offered credit on fixed interest rates for a period over one year (Bank of Ghana 2006). The banking sector suffers a shortage of capital and the funds from depositors are not large in amount or in terms of periods. Many banks manage to survive only because of transfer payments and cash operations. Getting credit from banks can also be complicated psychologically, as banks prefer to give credit to credible customers and enterprises they have been working together with for several years (CAL Bank 2005). Besides, the conditions of equipment finance on credit, payments and guarantees are softer and less aggressive in comparison with bank demands. There is a specific factor to the Ghanaian market that may in the short to medium term increase the attractiveness of equipment acquisition finance via leasing: the formulation of appropriate legal regimes that will facilitate repossession of assets in the event of default.

EQUIPMENT ACQUISITION FINANCE PROGRAMME: EXPERIENCES FROM THE DEFUNCT BANK FOR HOUSING AND CONSTRUCTION (BHC)

The Bank for Housing and Construction (BHC) of Ghana was a government-owned bank originally created as Development Finance Institutions (DFIs) to provide support for targeted construction activities in Ghana (Eyiah and Cook 2003). It was established to provide credit for private housing schemes, equipment financing schemes for contractors, expansion and modernization of immovable property, estates and industrial construction. At the time of its inception, the problems contractors faced in securing finance from established bank sources were imminent. Literature on the equipment finance programme for contractors by the BHC is limited. However, discussions were held with practitioners, academics and government officials to generate information for detailed coverage of the experiences of the contractor finance programme by the defunct BHC. The study by Eyiah and Cook (2003) was also consulted.

A considerable level of success was achieved at the initial stages of the equipment finance programme, until the emergence of several interrelated problems. Paramount of these was persistent delayed payments due to contractors by the government for works completed. Coupled with this, many of the beneficiaries lacked the managerial and technical capability to make a profit on projects in which they were engaged, or to secure more lucrative ones (Eyiah and Cook 2003). Efforts to address this latter problem had their own setbacks. While the assistant team, sponsored by the World Bank, was based in the regional capital (Accra), contractors who were to be supported came from all over the country with projects in different locations. The scope of assistance required and the number that needed support rendered services inadequate. These factors contributed to repayment default, although others defaulted deliberately. Inevitably, they were to provide collateral, hence abolishing a major objective of the programme. Notwithstanding, default payments became unbearable, prompting the bank to treat contractors with no preference. The next involvement of the BHC was the ‘Highway Projects’ and the Programme of Action to Mitigate the Social Cost of Adjustment (PAMSCAD) programme. The first concerned the government’s effort to rehabilitate and maintain the national road network. The second was part of government’s attempt to alleviate social tensions resulting from the adoption of the structural adjustment programme.

The BHC was involved in both programmes on a commercial basis. Funds received from donors were loaned to the bank. It then imported equipment and plant and supplied, on hire purchase, to the targeted group of contractors to enable the successful completion of specific projects. The problems encountered were no different from the previous experience. Highly notable was the acknowledgement by programme sponsors of the need for contractors to compete if they were to grow. Contracts were awarded on the basis of competitive tendering. While some contractors recognized this as an opportunity to engage in more lucrative projects, others saw it as a misfortune as they were not technically equipped to tender for contracts. Consequently, they could not service their equipment loans. There was also the problem of lack of spare parts to maintain equipment, and the generally poor managerial background of contractors meant many could not fully manage the equipment to effect maximum benefit. Furthermore, the contract agreement stipulated that payments for equipment supplied be made in the US dollar equivalent. The disparity between the Ghanaian currency (Cedi) and the US dollar overburdened contractors, resulting in default on repayments (Eyiah and Cook 2003). This resulted in erosion of capital base of the bank.

The involvement of the Social Security Bank (SSB) of Ghana in a similar programme was rather short-lived, after encountering similar problems. Its programmes could also be said to have been a pilot scheme, in that personnel contacted for discussion had no idea that the programme ever existed. Opinions on the practical and academic fronts in Ghana on ways to improve the effectiveness of financing programmes are diverse. There is, however, a consensus that contractors should establish a bank, which would be responsible for all their problems including the provision of finance. Two decades after BHC’s eventual liquidation, notable banks such as Amalgamated Bank and National Investment Bank (NIB) seem to be re-engineering equipment finance schemes in Ghana. Attempts made to produce detailed coverage of this re-engineering process proved futile since most often senior bank executives in charge were not available for discussion. Many are of the view that the sole responsibility of the government in programmes for contractors should be discouraged.

RESEARCH METHODS

The paper employed a combination of primary data (i.e. survey questionnaires) supplemented by secondary data (literature review) to present informative evidence of whether there is a financing gap between the construction sector and lending institutions in Ghana. In designing the questionnaire, efforts were made to ask questions, considering the background of respondents so as to generate understanding and interest. Where appropriate, therefore, we adopted questions of similar studies from Fawthrop (1969). In order to achieve strong theoretical underpinnings of the study, a number of factors had to be considered. First, demand and supply related factors leading to the perceived lending gap were established from literature. Second, questionnaires were formulated in line with the study objectives to solicit empirical data from two main sources: the demand side, consisting of a stratified sample size of 40 construction firms in Ghana; and the supply side, comprising 19 deposit-lending institutions. The respondent firms were selected based on set criteria, such as annual turnover, previous experience in sourcing for external finance for equipment purchases and equipment holding. Construction firms with annual turnover ranging between ¢1 and 10 billion Ghanaian Cedis were considered to have adequate funds to make equipment purchases from equity or retained profits without facing financing crunches in the future.

Previous applications to secure external finance were used as a criterion to collect relevant data to quantitatively appraise the magnitude of deficits in the supply of finance (financing gap) by lenders to contractors in Ghana. Equipment holdings of each firm were used as a criterion to validate the research findings as it provided an indication of the firm's involvement in equipment acquisition. The draft questionnaires were discussed with researchers in Ghana. The updated questionnaires were pre-tested with three contractors and three bankers who had previously been involved in research programmes. The final versions of the questionnaires were packaged into a booklet format as recommended by Dillman (1978). It was imperative to ensure that the right questions were asked, well understood and asked in the right way and the right respondents handled it (Fadhley 1991; Wahab 1996). The questionnaires were administered to the contractors by using the registered list of Association of Building and Civil Contractors of Ghana (ABCCG). A follow-up visit to the respondents to remind them of the agenda concerning the completion of the questionnaires was made via telephone calls, emails and personal visits. The data were gathered and processed into a suitable form for the analysis (thus, sorting, editing, coding, etc.). Descriptive statistics, data reduction (factor analysis) and linear regression were employed to analyse the data.

PRESENTATION OF THE ANALYSIS

Forty questionnaires were dispatched to targeted construction firms; 22 were returned completed. Also, 10 out of 19 of those despatched to the lending institutions were received completed. Response rates of 55% and 52.6% from contractors and banks respectively were used in performing the analysis. The apparently high response rates, compared to those registered in the studies by Easterly (1999), Galizia and Steinberger (2001) and Eyiah and Cook (2003) which had respective response rates of 37%, 49% and 61%, can be attributed to the technique employed in distributing the questionnaires. The analytical procedures employed were aimed at establishing whether there is a gap in the lending system regarding funding capital equipment acquisition. Weights were assigned to levels of agreement attached to variables on a five-point scale. The mean ratings of the variables were obtained using the sum total of points obtained and the number of responses for that particular variable (Everritt and Dunn 1991; Lynn *et al*. 2001). The data from the survey were mostly categorical data with groupings of variables; therefore, factor analysis was used to determine the predominant factors causing the effects. While linear regression analysis was used to model the relationships between demand and supply factors, the t-test was used to test the significance of some variables on the effects.

Table 1 shows that a significant majority of the respondents representing 87.5% agreed that a financing gap existed.

Table 1: Descriptive statistics showing valid percentage of existence of financing gap (Researcher's field survey 2006)

		Frequency	Percent	Valid percent	Cumulative percent
Valid		1	3.1	3.1	3.1
	No	3	9.4	9.4	12.5
	Yes	28	87.5	87.5	100
	Total	32	100	100	

A further analysis using regression was performed to test whether there is a significant relationship between demand and supply of funds which was an interest of the investigation. As indicated in Tables 2 and 3 below, the high regression coefficient value (R) of 0.73 is an indication of a strong linear relation between demand and supply.

Table 2: Regression coefficients (A) (Researcher's field survey 2006)

Model		Unstandardized coefficients		Standardized coefficients	t
		B	Std. error	Beta	
1	Constant	528.707	95.274		5.549
	Supply	0.868	0.145	0.738	5.986

Note: Dependent variable: demand.

Table 3: Model summary (B) (Researcher's field survey 2006)

Model	R	R-Square	Adjusted R-Square	Std. error of the estimate
1	0.738(a)	0.544	0.529	299.108

Note: Predictors: (constant), supply; dependent variable: demand.

The apparent huge difference in the mean difference and lower and upper limits difference at 95% confidence interval as demonstrated by t-values in Table 4 below has confirmed the existence of a financing gap in the Ghanaian construction industry.

Table 4: One-sample t-test (Researcher's field survey 2006)

	Test value = 0					
	t	df	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
Supply	8.346	31	0.000	546.875	413.23	680.52
Demand	13.019	31	0.000	1003.125	845.97	1160.28

This gap took the form of inadequacy or unavailability of institutional short-, medium- and long-term finance to the construction sector. Apparently, both demand side (construction firms) and supply side (financial institutions and central bank of Ghana) contribute to the obvious financing gap. Several factors were attributed to the evident financing gap. On the supply side the following factors were identified as contributing factors: lack of adequate credit policies or special programmes for construction; failure to establish a legal framework within which the banks can effectively operate; inability of the banks to mobilize long-term deposits. Other factors included stringent lending conditions and high lending costs as most often, borrowers are frustrated by the bureaucratic lending procedures and associated lending costs surcharged as processing fee on the facility. The factor analysis performed on these variables to identify the predominant factors causing the effect revealed two possible chief factors, namely the lending policy measures of the financial institutions and the financial strength of the lending banks.

DISCUSSION

Financing channels of the construction sector in Ghana: bank lending as the principal source

When respondent contractors were asked to indicate and specify the principal sources of finance that they relied on for equipment acquisition, the majority indicated bank financing, mostly commercial banks as their principal source. The descriptive statistical test showed quite a significant contribution by merchant and development banks, while leasing and insurance companies, though seen as promising equipment financing alternatives, revealed a marginal contribution so far. Other financing channels such as building societies, finance houses, trust houses, discount houses and mortgage institutions traded poorly. Empirical evidence from representative field results shows that while the majority of the banks are drifting from construction funding, a significant number of the contractors considered bank financing. The interpretation of this analogue is simple: lending institutions may receive several applications for credit facilities from various contractors with varying degrees of capitalization and perhaps grant a few. From our investigation, the supply of credit finance decreases monotonically while demand increases with interest rates.

However, excess demand for credit is common, as applications for credit are frequently not satisfied and this is very consistent with the experiences from developing countries. As a result, the demand for credit finance exceeds the supply at the market interest rate at any given time. This apparent evidence is an indication that demand from contractors far exceeds supply. There is also the possibility of a drop in credit supply to the construction sector as most lenders are retreating from construction finance because of the perceived high risk associated with construction finance. Similarly, the drop in both corporate and bank balance sheets may reduce the latter's willingness to lend, and potentially lead to a flight to quality and credit rationing. The empirical findings of the research confirm the initial research questions and basic hypothesis of the investigation. When the respondents were asked to indicate whether or not a financing gap exists, the overwhelming number represented by 87.5% (Table 1) indicated that there is a financing gap in the lending system of Ghana regarding construction funding (capital equipment funding). Similarly, it was identified from the empirical results that the following 'demand' factors contribute to the apparent financing gap: deficiencies in financial and managerial skills (as this was measured by the lack of experience in the field of activity, inadequate educational background, discrepancies in financial reporting systems, absence of feasibility studies or business plan, etc.); lack of adequate accounting or financial control systems; absence of forward planning; inability of construction firms to provide acceptable limits of collateral and inability to repay loan funds on time.

Collective stakeholder involvement and the way forward towards bridging the financing gap

Various measures have to be constituted to meet both the short-term and long-term financing needs of construction firms, especially capital equipment finance in Ghana. The factor analysis performed on the possible measures to close the perceived gap showed strong coefficient values of more than 0.5 indicating that, if those measures are observed, it will help close the gap. The majority of the respondents were of the view that a specialized ‘contractor bank’ be established solely dedicated to the construction sector as it used to be during the last three decades where Ghana had such a bank. The experiences of the defunct Bank of Housing and Construction (BHC) raised another issue that merits another study. Putting in place a specialized contractor bank has the added advantage of the proposed bank enjoying some protection in times of credit roaring. Similarly, there is the possibility of enjoyment of favourable operating conditions and benefits by both borrowers and lenders alike.

The factor analyses presented placed significant emphasis on the establishment of appropriate and adequate legal frameworks and lending policies within which lenders and borrowers can effectively operate. Observation from the analysis is consistent with the earlier claim by Aryeetey *et al*. (1997) that countries with operational legal systems have more developed financial markets and competitive access to external finance. This would suggest that there is an additional, indirect, channel through which sound laws, legal framework and judicial efficiency affect firms’ access to bank finance. Audretsch and Elston (1995) and Aryeetey (1993) however, found that financial market development affects both the growth in the average size of existing establishments and the growth in the number of new establishments as most industry is dependent on external finance. Thus, the theoretical effect of the development of financial markets on the average size of firms is ambiguous. On the one hand, more firms will be born, reducing the average size of firms. On the other hand, existing firms will be able to grow faster, increasing the average size of firms. Subsidizing interest rates, provision of re-discounting facilities and sharing risks with the government through special arrangements were among highly ranked measures towards bridging the perceived financing gap.

CONCLUSION, RECOMMENDATIONS AND AGENDA FOR FUTURE RESEARCH

The research has investigated the existence of a financing gap in the lending system of Ghana regarding capital equipment finance with empirical data. As such, this paper has demonstrated the existence of such a gap and several interrelated factors accounted for this lapse. Notwithstanding the crucial role of the construction sector towards Ghana’s strategic goal of attaining middle-income status by the year 2020, it is surprising that efforts to enhance the industry’s continuous contribution, with respect to the provision of finance, have achieved little consideration by stakeholders involved. The paper confirmed the assertion of Eyiah and Cook that construction contractors in developing countries have witnessed a massive financial recess, acute growth and eventual liquidation. This has been rigorously challenged and attributed to the lack of collective involvement of stakeholders towards construction financing in Ghana. This has arguably led to the existence of the so-called lending gap regarding construction financing, as most often lenders are reluctant to extend credit to contractors in Ghana.

The study recorded that a high number of the respondents representing 87.5% considered that a financing gap does exist in the lending system of Ghana, and would want immediate stakeholder intervention. A further manifestation of the desperate need for external finance was high among the firms examined. So far, little has been achieved regarding financing of contractors' equipment acquisition financing by both lenders and government. The paper observed that commercial lending or bank financing is the principal source of contractors' funding in Ghana. Unfortunately, most lenders are not interested in the construction sector as their core business line. The paper identified that a few lenders considered contractor financing but with an average sectoral allocation of 5% of their annual proceeds to contractors, which is marginal in relative terms.

Empirically, the research has confirmed and validated the existence of a financing gap in the Ghanaian lending system with field evidence. The idea of establishing specialized bank designated to feed the construction industry in Ghana was weighted very high among the respondents. Since establishing a specialized bank would require investment in time, expertise, systems and methodologies, organizational structures, research would have to be undertaken to identify stakeholders that would want to participate, the role they could play and holistically develop strategies for overall national involvement. Alongside a specialized contractor bank, the paper recommends further research to explore the possibilities of establishing a credit bureau in Ghana since the apparent financing gap was attributed to the asymmetry in information provided by contractors.

REFERENCES

Aryeetey, E (1993) *Sectoral credit allocation policy and credit flows to small enterprises in Ghana.* The British Council.

Aryeetey, E, Baah-Nuakoh, A, Duggleby, T, Heeeeettige, H and Steel, W (1994) Supply and demand for finance of small enterprise in Ghana. World Bank Discussion Paper No. 251.

Aryeetey, E, Hemamata, H, Nissanke, M and Steel, W (1997) Financial market fragmentation and reforms in Ghana, Malawi, Nigeria and Tanzania. *World Bank Economics Review*, **11**(2), 197–218.

Audretsch, B and Elston, J A (1995) Does firm size matter? Evidence on the impacts of liquidity constraints on firms investment behaviour in Germany. CEPR Discussion Paper No. 1072, November.

Bank of Ghana (2000) *Annual review*.

Bank of Ghana (2006) *Annual review.*

Bates, J (1960) The Macmillan gap, thirty years after. *The Banker*.

CAL Bank (2005) *Annual review*.

Dillman, D A (1978) *Mail and internet surveys: the tailored design method*. John Wiley & Sons Publications.

Easterly, W (1999) The ghost of financing gap: testing the growth model used in the international financial institutions. *Journal of Development Economics*, **60**(2), 423–38.

Edwards, D J, Holt, G D and Harris, F C (1998) Financial management of construction plant: conceptualizing cost prediction. *Journal of Financial Management of Property and Construction*, **3**(2), 59–73.

Everritt, B S and Dunn, G (1991) *Applied multivariate data analysis*. Edward Arnold Publishers.

Eyiah, A K and Cook, P (2003) Financing small and medium-scale contractors in developing countries: a Ghana case study. *Construction Management and Economics*, **21**, 357–67.

Fadhley, S A (1991) *A study of project finance banking with special reference to the determinants of investment strategy*, Unpublished Doctoral Thesis submitted to Loughborough University.

Fawthrop, R A (1969) *Criteria for comparative evaluation, selection and integration of methods of financing industrial capital expenditure*, Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University, UK.

Federal Reserve System of USA (1958) *Review report*.

Galizia, F (2003) Measuring the savings gap of European corporations, an update. *Economic and Financial Report*, European Investment Bank.

Galizia, F and Steinberger, T (2001) Measuring the financing gap of European corporations, an update. *Economic and Financial Report*.

Ghana Highway Authority (2002) *Annual review*.

Ghana Highway Authority (2004) *Annual review*.

Lynn, P, Beerten, R, Laiho, J and Martin, J (2001) Recommended standard final outcome categories and standard definitions of response rate for social surveys. Working Paper, University of Essex, Colchester.

Macmillan Report (1931) *Report of the Committee of Finance and Industry*, Cmnd 3897. London: HMSO.

Ray, G and Hutchinson, P J (1983) *The financing gap and financial control of small enterprise developments*. London: Gower.

Shawa, H H (1995) *Project finance for construction contractors operating in the United Arab Emirates*, Unpublished Doctoral Thesis submitted to Loughborough University.

Stole and Curley (1970) Small business and the new issue market for equities. *Journal of Finance and Quantitative Analysis*.

Taylor, L (1994) Gap models. *Journal of Development Economics*, **45**, 17–34.

Viswanath, P V (1999) Asset based financing techniques: the case of leasing.

Wahab, I A (1996) *Financing the growth of small manufacturing firms*, Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of Loughborough University, UK.

QUANTIFYING IMPACT FACTORS OF CORPORATE FINANCING: ENGINEERING CONSULTING FIRMS

Jieh-Haur Chen[1]

Institute of Construction Engineering and Management, College of Engineering, National Central University, 300 Jhungda Rd, Jhungli, Taoyuan 32001, Taiwan

The objective of this research is to identify and quantify the factors that influence corporate financing for engineering consulting companies in Taiwan. The quantification, thus derived based on statistical analyses, expresses the features of the engineering consulting market that fit the company's criteria for considerations of corporate financing. An initial survey of 118 professionals serving in both the financial and engineering consulting markets was conducted from which 36 points that influence the approval of corporate financing were summarized. The significance and quantification of the financing factors was determined from a comprehensive survey, via questionnaire, and factor analysis of two populations, comprising a total of 1124 firms and institutions. The conclusions give us 14 significant factors that can be classified into four component groups: for repayment-explained financing purposes, the corporate perspective, project features and public relations, and financing protection with corresponding weights being 0.328, 0.270, 0.214 and 0.188, respectively. In comparison with the most commonly accepted principle of financing, 5 principles (5P), accepted by financial institutions for years, these four weighted components provide a better basis for conducting corporate financing, and a quantification measurement method for corporate financing for both practice and research.

Keywords: construction industry, construction management, corporate governance, factor analysis, finance.

INTRODUCTION

The financing of engineering consulting firms by using corporate financing is not restricted by the status of their shareholders, executive officers or any particular individuals. Financial institutions for years have used the five principles (5P) of: person, purpose, payment, protection and perspective proposed by Paul H. Hunn as the basis for their financing decisions. Business types and features usually influence corporate financing; nonetheless, the process of financing approval is confidential and inconsistent regardless of the financial institution. It is often puzzling as to which weights of factors influence financing approval towards corporate financing for engineering consulting firms. This problem is an impediment as to how well firms in the engineering consulting market face competition or even develop. The objective of this research is to identify and quantify the factors that influence corporate financing so as to raise financing practicability.

[1] jhchen@ncu.edu.tw

CORPORATE FINANCING

The use of credit rating as a basis to evaluate companies has been accepted by the financial market for years. The 5P system has been commonly utilized to establish credit rating, and as the basis of loan approval. Some studies have emphasized that approval of financing is dependent upon an enterprise's features, credit record and market characteristics. The credit scoring system acts as a basis for analysing the financing parameters, and also for approving loans. The use of the debit–asset ratio, working capital and sales forecasting to establish the credit rating model has assisted banks in assessing the feasibility of loans. Studies also analyse other concepts for loaning issues. From the social viewpoint, loans create opportunities for small and medium scale enterprises as well as for workers. This is connected to loan guarantees. Researchers also suggest that the non-performing loan ratio may stay within a certain range for most financial institutions (Riding and Hanies 2001). Explicating the relationship between the borrower, the bank and the financing process directly affects the cost of the loan, risk management and information. One of the major findings concludes that banks with less capital ask for higher interest rates for loans than do those with better financial strength (Hubbard *et al*. 2002). Additionally, there are three benefits derived for enterprises with long relationships to financial institutions: relatively low credit costs, low limitations of collateral, and more alternatives for requesting loans when facing financial difficulties (Bodenhorn 2003).

For engineering consulting firms, the cost of capital determines the probability of obtaining bank loans (Besley and Brigham 2000). Nonetheless, 66.28% of the total capital used for construction projects is supplied by financial institutions (Price and Shawa 1997). For both manufacturing-oriented projects such as residential construction projects, and service-oriented projects such as professional construction management (PCM) projects, funding gaps depend on project activity arrangements. There has been no research in the finance-related literature, for either the construction industry or the engineering consulting market, undertaken to quantify impact factors for corporate financing.

RESEARCH METHODOLOGY

The modified Delphi method was used in this paper to explore the impact factors considered for corporate financing. The modified Delphi method is based on amendment through open discussion with the intent to obtain expertise during the beginning stage. Researchers suggest that expert interviews can be integrated with open discussion to develop a questionnaire. It is particularly feasible to apply this strategy to an area that has a limited number of studies and sources (Murry and Hammons 1995). Owing to limitations in the literature regarding the corporate finance of engineering consulting firms, expertise from industrial professionals, scholars and government officials, from both the financial and engineering consulting markets, was considered during the first step: 35 experts comprising 15 engineering consulting professionals, whose average working experience was around 20 years, and 20 banking professionals, whose average working experience was approximately 15 years, were interviewed. These 35 professionals were among the top managers from both markets and were recommended based on the top company list. Another randomly selected 83 professionals, whose average working experience reached 10 years, participated in two workshops and three conferences conducted to discover the impact factors. In total 118 professionals serving in 102 different firms or institutions, or affiliated with 45 different associations were selected. These firms and institutions comprise 60 engineering consulting firms and 42 financial institutions, and belong to 36 engineering-related and nine finance-related associations. Additionally, nine high-ranking government officials and five finance and engineering professors attended all the conferences and workshops. The process of impact identification, provision of expertise and suggestions for possible enhancement, for either this research or society, lasted approximately eight months. A total of 36 initial impact points were concluded, as shown in Figure 1, and 13 corresponding document formats were also collected. These points were collected from the brainstorming of experts' experience in the first conference. Based on each point's similarity and characteristics, expertise suggested that all initial points could be collected into 15 factors to be examined during the rest of the conferences and workshops.

Nationwide survey

An industrial survey was conducted by questionnaire to gather information for further analysis of these 15 factors. The questionnaire was aimed at both the engineering consulting and financial markets and involved two sections: one to gather basic information about the interviewee from the investigated company and the other one comprising 16 stems with a corresponding scale which allowed people to express their agreement with the corresponding statement. The first 15 stems follow the order of the 15 factors listed in the right-hand column of Figure 1 and the last stem is designed to catch any possible additional factors that the interviewee may consider to have an influence on corporate financing. Since professionals in these markets have totally different backgrounds, the utilization of a simple form of questionnaire is desired. The widely accepted Likert-type scale for the assessing of attitudes is used. The five choices are 'extremely high impact', 'high impact', 'medium impact', 'low impact' and 'little or no impact'. These 16 stems are listed in Table 1. The nationwide survey targeted all 691 professional engineering consulting firms and all 433 financial institutions registered in 2005; 1124 questionnaires were distributed to their headquarters. Within a month, 245 questionnaire responses were returned. Of these 245 questionnaires, 12 were invalid. The response rate was only 20% owing to the volunteer-oriented basis.

Factor analysis

Conducting factor analysis for the returned questionnaires requires fulfilment of two statistical assumptions: a sample size greater than 200, or greater than the number of stems multiplied by 5. It can be seen that the survey satisfies both minimum sample size requirements. Table 2 shows the mean, standard deviation, mean variance, kurtosis and skewness for each stem. Among all 233 respondents, only nine respondents answered Stem No. 16, representing less than 5% of the total. From the statistical viewpoint, this is insignificant and can be ignored. There was a major difference in the response to Stem No. 9, 10 and 13. In comparison with financial firms the professional engineering consulting firms considered the degree of impact for each factor to be less. This means that even though professional engineering consulting firms understand basic concepts of financing, they underestimate the importance of each factor, which leads to difficulty or even failure to meet the explanation or description of factors considered important by financial institutions.

For market feature analysis, the Bartlett's sphericity test and Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy are used to examine the appropriateness of factor analysis adopted to achieve the research objective. By matching the following factor analysis assumptions: (1) reducing a large number of variables to a smaller number of factors for modelling purposes; and (2) creating a set of factors to be treated as uncorrelated variables, we get the results in Table 3, which demonstrate the Bartlett's test and KMO measure results. The value of KMO overall varies from 0 to 1 but it should be equal to 0.6 or higher to proceed with factor analysis. A higher KMO overall expresses greater appropriateness for the conducting of factor analysis on the database. The sum of the KMO overall in this research database is 0.832 which is of course greater than 0.6. The significance level for the sphericity test ranges from 0 to 1, and represents appropriateness for the carrying out of factor analysis. The default value of the significance level is typically equal to 0.05. Accordingly, the significance level of the database at 2.04×10^{-198} (extremely close to 0) which means that there is a high correlation and that it is appropriate to adopt factor analysis to the database.

Table 1: Stems of questionnaire

Stem No.	Factor descriptions and stems
1.	Do descriptions of funds needed influence the financing mechanism between a financial institution and an engineering consulting firm?
2.	Do descriptions of financial status influence the financing mechanism between a financial institution and an engineering consulting firm?
3.	Does profitability influence the financing mechanism between a financial institution and an engineering consulting firm?
4.	Does goodwill influence the financing mechanism between a financial institution and an engineering consulting firm?
5.	Do corporate credit records influence the financing mechanism between a financial institution and an engineering consulting firm?
6.	Does any project contract influence the financing mechanism between a financial institution and an engineering consulting firm?
7.	Do any project size and duration influence the financing mechanism between a financial institution and an engineering consulting firm?
8.	Do financing amount and its length of period influence the financing mechanism between a financial institution and an engineering consulting firm?
9.	Do descriptions of cash flows influence the financing mechanism between a financial institution and an engineering consulting firm?
10.	Do descriptions of a repayment plan influence the financing mechanism between a financial institution and an engineering consulting firm?
11.	Does availability of collaterals influence the financing mechanism between a financial institution and an engineering consulting firm?
12.	Do types of collaterals influence the financing mechanism between a financial institution and an engineering consulting firm?
13.	Does the use of separate project account influence the financing mechanism between a financial institution and an engineering consulting firm?
14.	Does promotion by the government influence the financing mechanism between a financial institution and an engineering consulting firm?
15.	Do public relations of the corresponding persons influence the financing mechanism between a financial institution and an engineering consulting firm?
16.	Is there any factor needed to list? Please name it and provide the ranking of impact.

Factor analysis included five main tests applicable to the purpose of this study; see Table 2. These five tests are missing value analysis, descriptive statistics, independent samples t-test, homogeneity test and consistency test. Missing data can seriously affect the results. Using missing value analysis to uncover missing data patterns helps to estimate summary statistics and impute missing values. Missing value analysis is done to diagnose whether the database has a serious missing data imputation problem, and to replace missing values with estimates. Here the default threshold is set to 0.05.

Description of fund needed Business interests Source of project Positioning Marketing strategy	→ Purpose of funds needed
Financial strength Firm size Sales Shareholder structure	→ Description of financial status
Successful project Operating performance Profitability record Corporate profitability	→ Profitability
Enterprise image Reputation Goodwill Owner's credit Perspective	→ Goodwill
Corporate credit record	→ Corporate credit record
Firm expertise Contract features of project	→ Project contract
Project size and duration Work activities of project	→ Project size and duration
Financing amount and length of period	→ Financing amount and length of period
Description of cash flows Firm capacity	→ Description of cash flows
Description of repayment plan Guarantor status	→ Description of repayment plan
Collateral availability	→ Collateral availability
Collateral type	→ Collateral type
Use of separate project account	→ Use of separate project account
Promotion by the government	→ Promotion by the government
Human resource Public relations Interpersonal relationship Attitude of the corresponding persons	→ Public relations of the corresponding persons

Figure 1: Induction of corporate financing impact factors

Descriptive statistics are numbers that are used to summarize and describe data. Any other number chosen for the computation also counts as a descriptive statistic for the data from which the statistic is computed. Several descriptive statistics are often used at one time to give a full picture of the data. In this study, a mean value greater than 3 is recommended, representing a greater degree of impact than the average. Accordingly, it is recommended that the thresholds for standard deviation and skewness be set to 0.8 and 0.5 respectively. The independent sample t-test allows for a comparison of the mean scores of two groups for a given variable. When the p-value is less than 0.05, the two groups have significantly different means. The homogeneity test can be thought of as a test of the conformity of the difference between two means. In a homogeneity test, the principal component analysis, scree test and factor loading test are adopted to select factors appropriately. Here, the suggested factor loading, correlation coefficient and KMO thresholds are 0.3, 0.3 and 0.7, respectively. A consistency test is conducted to evaluate the reliability of the questionnaire. Cronbach's alpha is used to assist in carrying out the consistency test and suggests that each alpha value of the tested factors should be greater than 0.7, standing for high reliability (Hair *et al*. 1998; Chiu 2004; Wang 2004). Table 4 demonstrates the results of these five tests. A comparison of the 15 Cronbach's alpha values to the suggested thresholds confirms the reliability of the questionnaire. Factor No. 14, promotion by the government, has three testing results below the thresholds so it is suggested that this be removed. Factors No. 5, 6, 7, 8, 11, 12 and 15 have either one or two testing results below the thresholds, so it is suggested that the five main tests be conducted for the remaining 14 factors after deleting No. 14.

Table 2: Basic statistical information of stems

Stem	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Answered by financial institutions (153)															
Mean	1.68	1.47	1.86	1.69	1.45	2.18	2.19	2.12	1.75	1.35	1.79	1.96	1.62	2.53	2.47
Standard Deviation	0.85	0.68	0.74	0.69	0.66	0.81	0.74	0.81	0.75	0.66	0.82	0.75	0.73	0.89	0.84
Mean Variance	0.73	0.46	0.55	0.47	0.43	0.66	0.55	0.66	0.57	0.44	0.68	0.56	0.54	0.80	0.71
Kurtosis	1.84	0.83	–0.12	–0.82	1.10	–0.68	–0.43	–0.45	–0.35	4.26	0.11	–0.36	0.21	0.24	0.46
Skewness	1.32	1.27	0.52	0.48	1.31	0.10	0.08	0.29	0.64	2.07	0.84	0.35	0.94	0.29	0.34
Answered by engineering consulting companies (80)															
Mean	2.25	1.89	2.11	1.96	1.58	2.58	2.49	2.43	2.44	2.15	1.92	2.10	2.75	2.72	2.47
Standard Deviation	1.14	1.10	0.91	0.99	0.83	1.17	1.02	1.03	1.02	0.99	1.15	1.07	1.19	1.34	1.06
Mean Variance	1.29	1.20	0.82	0.99	0.68	1.37	1.05	1.07	1.04	0.98	1.33	1.14	1.42	1.79	1.12
Kurtosis	–0.46	0.89	–0.81	–0.02	3.75	–0.43	0.12	–0.45	–0.40	0.93	1.67	1.00	–0.69	–1.14	–0.35
Skewness	0.61	1.25	0.30	0.80	1.76	0.53	0.50	0.41	0.42	0.91	1.49	1.15	0.32	0.33	0.55
Total (233)															
Mean	3.13	3.39	3.05	3.21	3.51	2.68	2.71	2.77	3.02	3.38	3.17	2.99	3.00	2.40	2.53
Standard Deviation	1.00	0.86	0.81	0.81	0.72	0.97	0.86	0.90	0.91	0.87	0.95	0.87	1.06	1.07	0.92
Mean Variance	0.99	0.75	0.65	0.66	0.52	0.93	0.73	0.81	0.84	0.76	0.90	0.76	1.12	1.14	0.84
Kurtosis	0.69	2.49	–0.36	0.44	2.97	0.21	0.48	–0.16	0.14	2.25	1.79	1.23	0.50	–0.28	0.14
Skewness	1.08	1.57	0.49	0.85	1.60	0.57	0.48	0.46	0.75	1.52	1.32	0.93	1.01	0.43	0.45

Table 3: KMO Measure and Bartlett's test to the database

KMO measure		0.832
Bartlett's test	Chi-square distribution	1201.435
	Degree of freedom	91
	Significance	0.000

Factor extraction is conducted to divide the group of 14 factors into a few sets before being compared to the current 5P basis. The scree test shown in Figure 2 implies that the 14 factors can be classified into four groups based on eigenvalue > 1. According to the literature it is suggested that there are six common methods for factor extraction.

Trial and error is used. It can be concluded that principle component analysis combined with orthogonal rotation and Kaiser-normalized varimax methods best fit the research goal. To determine the weight of each factor, one finds the common variance of all 14 factors; the results are shown in Table 5. Each factor has a corresponding extraction value as well as corresponding weight. Table 6 illustrates the results of grouping the four components obtained using an after-transformation component matrix. The four components determined based on transformation convergence (with seven iterations), are the: (1) repayment-explained financing purpose; (2) corporate perspective; (3) financing protection; and (4) project feature and public relations, according to each component's characteristics. Each component's weight is calculated using the sum of the corresponding factor weights listed in Table 5.

Table 4: Test results

No.	Factor	Missing value	Mean	Standard deviation	Skewness	T-test	Correlation coefficient	Factor loading	KMO	Cronbach's α
1.	Purpose of funds needed	0.00	3.129	0.996	1.167	0.00	0.589	0.538	0.893	0.841
2.	Description of financial status	0.00	3.391	0.865	1.581	0.00	0.616	0.599	0.84	0.842
3.	Profitability	0.00	3.052	0.808	0.870	0.00	0.589	0.400	0.891	0.843
4.	Goodwill	0.00	3.215	0.813	0.900	0.00	0.529	0.381	0.855	0.845
5.	Corporate credit record	0.00	3.506	0.720	1.816	0.00	0.492	0.406	0.814	0.849
6.	Project contract	0.00	2.682	0.966	0.600	0.00	0.488	0.386	0.894	0.843
7.	Project size and duration	0.00	2.708	0.856	0.519	0.00	0.550	0.539	0.858	0.843
8.	Financing amount and length of period	0.00	2.773	0.902	0.494	0.00	0.558	0.604	0.852	0.842
9.	Description of cash flows	0.00	3.017	0.914	0.779	0.00	0.688	0.586	0.904	0.834
10.	Description of repayment plan	0.00	3.378	0.873	1.581	0.00	0.661	0.471	0.905	0.838
11.	Collateral availability	0.00	3.167	0.948	1.384	0.00	0.363	0.896	0.591	0.854
12.	Collateral type	0.00	2.991	0.871	1.000	0.00	0.378	0.625	0.607	0.853
13.	Use of separate project account	0.00	3.000	1.059	0.987	0.00	0.549	0.515	0.818	0.845
14.	Promotion by the government	0.00	2.403	1.067	0.433	0.00	0.386	0.266	0.806	0.853
15.	Public relations of the corresponding persons	0.00	2.532	0.919	0.510	0.00	0.377	0.256	0.861	0.851
Threshold		**<0.05**	**>3**	**>0.8**	**>0.5**	**<0.05**	**>0.3**	**>0.3**	**>0.7**	**>0.8**

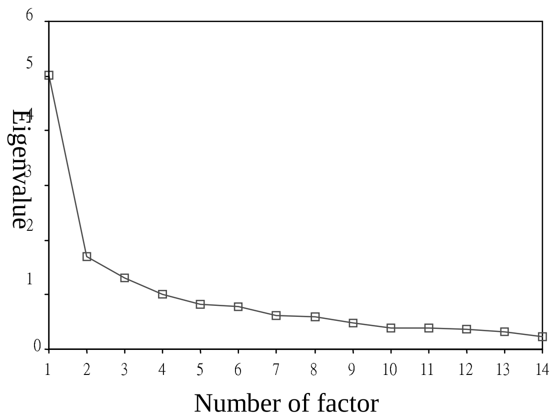


Figure 2: Scree plot

Table 5: Weights (Common variance) of 14 factors

	Initial	Extraction value (by principle component analysis)	Weight (%)
Factor No.1	1.000	0.641	7.100%
Factor No.2	1.000	0.657	7.277%
Factor No.3	1.000	0.513	5.682%
Factor No.4	1.000	0.604	6.690%
Factor No.5	1.000	0.659	7.300%
Factor No.6	1.000	0.468	5.184%
Factor No.7	1.000	0.646	7.156%
Factor No.8	1.000	0.643	7.122%
Factor No.9	1.000	0.664	7.355%
Factor No.10	1.000	0.574	6.358%
Factor No.11	1.000	0.852	9.437%
Factor No.12	1.000	0.849	9.404%
Factor No.13	1.000	0.611	6.768%
Factor No.15	1.000	0.647	7.167%

Table 6: Component matrix after transformation and corresponding weights

	Component			
	1	2	3	4
Factor No.13	***0.766***	-5.150×10^{-2}	4.598×10^{-2}	0.140
Factor No.9	***0.695***	0.332	0.145	0.225
Factor No.1	***0.651***	0.452	4.377×10^{-2}	–0.101
Factor No.10	***0.644***	0.301	0.216	0.146
Factor No.6	***0.610***	0.168	-5.413×10^{-2}	0.254
Factor No.5	3.549×10^{-3}	***0.797***	0.116	0.105
Factor No.4	0.174	***0.729***	-3.434×10^{-2}	0.203
Factor No.2	0.417	***0.641***	0.252	-9.388×10^{-2}
Factor No.3	0.326	***0.592***	5.376×10^{-3}	0.237
Factor No.11	5.271×10^{-2}	9.026×10^{-2}	***0.911***	0.109
Factor No.12	9.409×10^{-2}	7.004×10^{-2}	***0.909***	9.416×10^{-2}
Factor No.15	1.621×10^{-2}	0.113	0.209	***0.768***
Factor No.8	0.359	0.177	8.136×10^{-2}	***0.690***
Factor No.7	0.530	0.114	–0.103	***0.584***

FINDINGS AND DISCUSSION

The most common principle of financing, 5P, used by financial institutions is compared to the four weighted components that direct reconstruction of corporate financing. This study has suggested that there are both similarities and dissimilarities between 5P and the four weighted components, which are discussed below. Component 1 is named the repayment-explained financing purpose and involves five factors, all associated with financing purpose and repayment. The total weight of Component 1 is 32.766%. It matches the two Ps of 'purpose' and 'payment', and is the most important consideration. This finding suggests that the project contract is an important factor that needs to be taken into account by financial institutions. In Taiwan, financing procedures are equal or extremely similar for all industries. Most engineering consulting firms operate based on engineering projects which have the features of being highly customer-oriented transactions, long transaction procedures, involving a costly bidding process, and having a long-term plus wide-ranging impact on downstream products. Completing projects to fulfil contracts is where revenue comes from. These features affect contract performance deeply. The weight is 15.821% (= 5.184% ÷ 32.766%). This factor is considered in terms of the two Ps, 'purpose' and 'payment', and relatively redirects consideration for financial institutions. The finding for Component 1 indicates that the viewpoint of engineering consulting firms matches that of bankers. Financial institutions desire to clearly understand the reasons that they should support loan approval, and desire to secure repayment ability. The documents listed in Table 7 facilitate this understanding. Additionally, the use of separate project accounts limits the flexibility of working capital for engineering consulting firms. For financial institutions however, it lowers risks caused from uncertain and unidentified use of capital by the borrowers. A commitment to the use of separate project accounts has a weight of 20.656% (= 6.768% ÷ 32.766%) for consideration in two Ps. Component 2 stands for the corporate perspective, and includes four factors describing financial status, profitability, goodwill and corporation credit record. All these are related to corporation development and match the 'perspective' of 5P. The component's weight of 26.949% indicates that profitability and goodwill are significant. In other words companies that perform well earn trust for financing.

The next similarity lies in the fact that financial protection has been highly valued for years. Component 3 is related to the need of financial institutions to have protection for the approval of loans. This corresponds to the 'protection' of 5P. In Taiwan, the most preferred form of protection or collateral requested by bankers is plant assets. It is however unlikely that most engineering consulting firms would own many fixed assets such as construction equipment, land, or buildings. The weight of this component, 18.841%, suggests that most engineering consulting firms undergo some degree of difficulty in acquiring corporate financing. This finding reflects the current financing situation, and concludes no officially supporting document due to diversification of collateral. Component 4, public relations by corresponding persons, reveals a dissimilarity and partial similarity between the 5P and the weighted four components. The factor of public relations by corresponding persons is weighted as 7.167% to the total, and is partially related to the 'people' of 5P. People and project features are both involved in determining the proportion of the weighting of this factor. However, based on the nature of project performance, No. 7 and 8 factors are related to project features. A comprehensive understanding of the features of an engineering consulting project is not easily reachable for most financial professionals.

Table 7: Four components and their corresponding documents

Component No.	Component name	Weight	Factor	Corresponding document
1	Repayment-explained financing purpose	2.958 (32.766%)	■ Purpose of funds needed (No.1), ■ Project contract (No.6), ■ Description of cash flow (No.9), ■ Description of repayment plan (No.10), and ■ Use of separate project account (No.13)	■ Corporation basic information, ■ License, ■ Balance sheet, ■ Income statement, ■ Statement of cash flows, ■ Use of internal capital, and ■ Contracts
2	Corporate perspective	2.433 (26.949%)	■ Description of financial status (No.2), ■ Profitability (No.3), ■ Goodwill (No.4), and ■ Corporate credit record (No.5)	■ Financial statements, ■ Credit report, ■ CPA's financial report, ■ Operating performance records, and ■ Related enterprises' financial reports.
3	Financing protection	1.701 (18.841%)	■ Collateral availability (No.11)and ■ Collateral type (No.12)	No particular documents
4	Project feature and public relations	1.936 (21.444%)	■ Project size and duration (No.7), ■ Financing amount and length of period (No.8), and ■ Public relations of the corresponding persons (No.15)	■ Project schedule, ■ Schedule of on-going projects, contracts, and ■ Operating plans.

These two factors do not exist in 5P, but are weighted in our results as 14.278% of the total.

The findings indicate that there exists a margin at 14.278% or higher to adjust the consideration of corporate financing for engineering consulting firms. When conducting corporate financing, this margin represents the differential created by the market's characteristics. Although it is highly possible that the margin would vary with other markets or industries, the methodology and concepts used in this study can be used to adjust feasible corporate financing in practice. Likewise, the documents collected and their corresponding factors listed in Table 7 may help to unify and simplify the procedures of corporate financing. A common basis for corporate financing in the financial market is achievable.

CONCLUSION

The special characteristics of engineering consulting projects need to be considered during corporate financing as suggested through the interviews, conference and workshop discussions, and statistical analyses. The quantification discussed in this paper identifies 14 factors classified into four components that have an impact on corporate financing for engineering consulting firms in Taiwan. One of our goals is to help these firms understand which of these factors are more influential by looking at their corresponding weights. The attestation of the quantification is suggested through the use of expert interviews, a questionnaire survey and factor analysis. Comparison of the four components to the financial institutions' 5P model illustrates differential due to the special features of the engineering consulting market. Suggestions and findings provided by this study have an impact on both practice and research and state that a certain margin of adjustment should be considered for approving loans.

REFERENCES

Besley, S and Brigham, E F (2000) *Essentials of managerial finance*. Florida: The Dryden Press.

Bodenhorn, H (2003) Short-term loans and long-term relationships: relationship lending in early America. *Journal of Money, Credit, and Banking*, **35**(4), 485–505.

Chiu, H C (2004) *Quantitative research and statistical analysis in social and behavioral sciences*. Taiwan: Wunan.

Hair, J F J, Anderson, R E, Tatham, R L and Black, W C (1998) *Multivariate data analysis*. Upper Saddle River, NJ: Prentice Hall.

Hubbard, R G, Kuttner, K N and Palia, D N (2002) Are there bank effects in borrowers' costs of funds? Evidence from a matched sample of borrowers and banks. *Journal of Business*, **75**(4), 559–82.

Murry, J W and Hammons, J O (1995) Delphi: a versatile methodology for conducting qualitative research. *Review Higher Education*, **18**(4), 423–36.

Price, A D F and Shawa, H (1997) Survey of project related finance in United Arab Emirates. *Journal of Construction Engineering and Management*, **123**(3), 223–32.

Riding, A L and Haines, G (2001) Loan guarantees: costs of default and benefits to small firms. *Journal of Business Venturing*, **16**(6), 595–612.

Small and Medium Enterprise Administration (2005) *Act of development and promotion for small and medium enterprise*. Taiwan: Ministry of Economic Affairs.

Wang, P C (2004) *Multivariate analysis: statistical package and data analysis*. Taiwan: Advanced Education.

THE LAW RELATING TO DEFECTS: URGENT NEED FOR REVIEW

Philip Chan[1]

Department of Building, National University of Singapore, Singapore 117566

Two interesting developments have changed the legal positions of developers and subsequent purchasers in respect of building defects. Until recently, it appeared that developers were bound by the rule that if they do not suffer any loss as a result of defects they would only be entitled to nominal damages. Developers have always had the right to contractual remedies in respect of building. The recent cases have held that a developer is entitled to substantial damages even if the developer did not suffer any loss. In the law of negligence, the courts have held that a subsequent purchaser may not recover from the builder and/or designer. The Singapore courts departed from the English cases and held that the management corporation which is in charge of the maintenance of the common property of a development have a right to claim from both the developer and the architect pure economic loss in the form of the cost of repair of the building defects found in the common property. Accordingly, the law relating to defects appears to be unsatisfactory. This paper advocates a change in the law.

Keywords: contract, defects, developers, negligence, subsequent purchasers, substantial damages.

INTRODUCTION

In the realm of real estate, a builder who builds a structure with defects should be made liable for the cost of the repair of the defects or the loss in value of the structure. However, the real issue is to whom should a builder be liable. In the Commonwealth, where the common law system applies, it would appear that under the current English and Singapore law of contract, it is possible for a developer who has sold all the units in the development without suffering a loss to claim substantial damages from the builder. Further, in the English law of tort which Singapore usually applies with little or no modification, subsequent purchasers who have no contract with the builder are not able to recover from the builder, damages in respect of defects found in their property.

It would appear that the subsequent purchaser who is saddled with the defects has no recourse against the builder because of the principle of indeterminate number of plaintiffs claiming against the builder. On the other hand, the developer is entitled to recover substantial damages from the builder although he may not have suffered any loss when the development was completely sold without any loss because of the fear that no other person is entitled to recover from the builder; this has been referred to as the legal black hole.

[1] bdgccf@nus.edu.sg

Thus, the real issue is not whether a contract breaker like the builder should be made liable for defective works but whether a person like a subsequent purchaser who ends up paying for the cost of rectification of the defects or accepts a diminution in value of a structure with defects should be the proper party to be entitled to claim substantial damages instead of allowing a developer to claim substantial damages because it is riding on the slogan that encourages all to avoid the legal black hole like a plague.

This paper analyses the situation through two Singapore case studies to determine whether there is a legal solution to the current position that apparently boggles the minds of most people and puts humanity into a legal framework that works rigidly within the constraints of binding judicial precedent that has a tendency to increase incrementally regardless of the need of an urgent change. This paper examines the two cases within the law of contract framework and the law of professional negligence.

REVIEW OF CASES

The first part of this section reviews the cases on the contract law point on a substantial damages claim where no loss is suffered while the second part examines the cases on the pure economic loss point in professional negligence.

Substantial damages claim cases

The landmark case that is responsible for the opening up of discussion in this paper is the case of *Dunlop* v. *Lambert* (1839) 6 Cl & Fin 600; 7 ER 824. This case has been known as being the exception to the general rule that 'only the person who has suffered the loss would be entitled to have it made good by compensation'.[1] The court in *Dunlop* v. *Lambert* held that the party that shipped goods could recover substantial damages from the carrier as the goods were lost due to a general average sacrifice although by the time the action was taken, the goods were not the party's property or at its risk. However, the said party would be accountable to the true owner for the proceeds of the judgment.

Subsequently, the Bills of Lading Act 1855 (c. 111) which provided for the automatic assignment of the rights of action for breach reduced the importance of the said landmark case. In more recent times in *The Albazero* [1977] AC 774, the House of Lords were of the view that the exception created by *Dunlop* v. *Lambert* should not be unnecessarily extended. Bearing in mind that the rule in *Dunlop* v. *Lambert* was created to get around the undesirable consequences of the privity of contract rule, there would be no such undesirable consequences if it is within contemplation that the carrier will also enter into separate contracts of carriage with whoever may become the owner of goods carried pursuant to the original contract.[2]

While the above-mentioned principles evolved, the subject matter remained that of goods. By 1994, the subject matter extended to immoveable property. The *Dunlop* v. *Lambert* exception was used in a building contract case named *St Martins Property Corporation Ltd* v. *Sir Robert McAlpine Ltd* [1994] 1 AC 85. In this case, there was a concern that because it could be foreseen that the development was going to be occupied and possibly purchased by third parties, any damage caused by a breach of contract on the part of the builder in the form of defects in the development would cause loss to a later owner and not merely to the original contracting party. Indeed, it was an express provision that prohibited the assignment of rights without consent.

The court held that it was proper 'to treat the parties as having entered into the contract on the footing that the [developer] would be entitled to enforce contractual rights for the benefit of those who suffered from defective performance but who, under the terms of the contract, could not acquire any right to hold [the builder] liable for breach'. The basis relied on is known as the narrow ground. This ground also likens the situation to a legal black hole where any possible claims against the builder are sucked into the legal black hole with no one in a position to sue the builder.

To allay the fears of builders who have given warranties to subsequent purchasers, the court held that the *Dunlop* v. *Lambert* exception would not apply to those cases. Another interesting point arose in this case which differentiated from the goods cases.

The court also held that there is further reason why the developer should be allowed to claim substantial damages. It was explained that the developer should be allowed to recover substantial damages as the developer suffered a loss of its 'performance interest'. The basis relied on is known as the broad ground.

Like the earlier goods cases, the legal brakes were applied to the evolution of the *Dunlop* v. *Lambert* exception in immoveable property cases. In *Alfred McAlpine Construction Ltd* v. *Panatown Ltd* [2001] 1 AC 518, it was held that the developer was not entitled to claim substantial damages from the builder for breach of contract because the builder also entered into a duty of care deed with the owner of the site. This was viewed as giving the site owner a direct remedy against the builder in respect of any failure by the builder to exercise reasonable skill, care and attention in carrying out its obligations under the main contract.[3] However, the minority view in this case advocated that the existence of a right of the site owner to claim against the builder should not deprive the developer from recovering for breach of the building contract.

Indeed Lord Millett noted that, 'The problem, in my view, is not one of double recovery, but of ensuring that the damages are paid to the right party.'

Pure economic loss cases

Until more recently, legal damages were categorized as arising from death, personal injury and damage to property. The earliest mention of the relationship between a builder and a subsequent purchaser appears to be an obiter statement of Lord Wilberforce in *Anns & Ors* v. *London Borough Council of Merton* [1978] AC 728. He held (at 758–9) that a builder of defective premises would be liable in negligence to a person who subsequently acquired the house and who sustained injury. In particular, the Law Lord explained (at 759) that, 'the relevant damage is in my opinion material, physical damage, and what is recoverable is the amount of expenditure necessary to restore the dwelling to a condition in which it is no longer a danger to the health or safety of persons occupying and possibly (depending on the circumstances) expenses arising from necessary displacement.'

This case was followed by *Junior Books Ltd* v. *Veitchi Co Ltd* [1983] 1 AC 520. It was an appeal to the House of Lords from the Court of Sessions in Scotland. It was held that the nominated subcontractor was liable to the owner in respect of the cost of replacing the floor as the subcontractor had negligently laid the floor which was defective. The Law Lords had applied the *Anns* two-stage test. Essentially, in respect of the first stage, it was held that the nominated subcontractor must have known that if they did the work negligently the resulting defects would at some time require remedying by the owner expending money upon the remedial measures as a consequence of which the owner would suffer financial or economic loss. In respect of the second stage, Lord Roskill held that there should be no reason why the type of damage recoverable under negligence should not be extended to pure economic loss.

> But in the present case the only suggested reason for limiting the damage (ex hypothesi economic or financial only) recoverable for the breach of the duty of care just enunciated is that hitherto the law has not allowed such recovery and therefore ought not in the future to do so. My Lords, with all respect to those who find this a sufficient answer I do not. I think this is the next logical step forward in the development of this branch of the law. I see no reason why what was called during the argument 'damage to the pocket' simpliciter should be disallowed when 'damage to the pocket' coupled with physical damage has hitherto always been allowed. I do not think that this development, if development it be, will lead to untoward consequences.

Some years later, the House of Lords in *D & F Estates Ltd & Ors* v. *Church Commissioners for England & Ors* [1989] AC 177 appeared to have gone into a reverse gear. It was held that the liability of a builder of a permanent structure which was dangerous effectively arose only if the defects remained and caused personal injury or damage to property other than the structure itself. Further, if the defects were discovered before any such injury or damage was caused, the loss of the owner of the structure in repairing or rectifying defects would be purely economic and was not recoverable. However, it should be noted that the case of *Junior Books* has not really been expressly overruled in *D & F Estates* or in subsequent cases.

Then came *Murphy* v. *Brentwood District Council* [1990] 2 All ER 908. Lord Harwich said (at 926):

> If a builder erects a structure containing a latent defect which renders it dangerous to persons or property, he will be liable in tort for injury to persons or damage to property resulting from that dangerous defect. But if the defect becomes apparent before any injury or damage has been caused, the loss sustained by the building owner is purely economic. If the defect can be repaired at economic cost, that is the measure of the loss. If the building cannot be repaired, it may have to be abandoned as unfit for occupation and therefore valueless. These economic losses are recoverable if they flow from breach of a relevant contractual duty, but, here again, in the absence of a special relationship of proximity they are not recoverable in tort.

It should be noted that in one form or other, pure economic loss cases have been influenced by the observations of the great American judge, Cardozo CJ, in *Ultramares Corporation* v. *Touche* 174 NE 441 (1931) where he expounded on the oft-quoted of 'liability in an indeterminate amount for an indeterminate time to an indeterminate class' (at 444) which ought to be avoided. This has been the guiding light for many if not all pure economic loss cases.

OBSERVATIONS ON CASES REVIEWED

Substantial damages claim cases

The *Dunlop* case represents an exception to the general rule that a person can claim substantial damages only if the person suffers a loss. Its main purpose is to overcome the problem created by the doctrine of privity of contract where the actual sufferers cannot make a claim against the person who created the suffering because the two do not have a contract with each other. It is also important to note that the exception applies such that the person who suffers no loss but is entitled to recover substantial damages is able to do so because this person remains accountable to the actual sufferer. Further, the *Dunlop* case applied where the subject matter of the loss concerns goods that are shipped. Subsequently, the *Dunlop* exception is seldom invoked because subsequent legislation addressed the issue of the lack of privity of contract.

Having set out the salient features of the *Dunlop* case, it can be established that under the current laws, the application of the principle to loss suffered in respect of immoveable property may not be appropriate. Addressing the privity of contract point, it can be seen that unless parties have excluded the application of the Contract (Rights of Third Parties) Act 1999, a purchaser who purchased from the developer ought to be able to sue the builder pursuant to the Act unless the application of the Act has been excluded. Perhaps one solution is to remove the right to exclude the application of the Act in respect of building contracts.

In addition, there may not be an issue of the purchaser suffering a loss if the purchaser buys an existing immoveable property that has patent defects since the principle of caveat emptor applies though this may not apply in England in its common law form as a result of statutory intervention. At least in theory parties who buy and sell immoveable property would in all likelihood include the existence of defects as part of the factors for consideration in agreeing to a sale and purchase price. However, the issue of latent defects remains un-addressed. This opportunity to negotiate a price to take into account loss suffered as a result of patent defects would have addressed the situation in *Dunlop* where it is not possible to reduce the price for the buyer of the goods at the time when the property and the risk transfer to the buyer of the goods in respect of any damage caused by the shipper.

Pure economic loss cases

While the development of the law of negligence in England and Wales appears to concentrate on controlling the front end by imposing the need to establish the existence of a special relationship of proximity, the American approach looks towards avoiding a result that produces ‘liability in an indeterminate amount for an indeterminate time to an indeterminate class’. The other jurisdictions are then compelled to consider both forms of control in seeking an answer.

Such is the richness of the tradition of judge-made law, it would probably take decades for the learned judges to be freed from the shackles of the precedents so as to figure out a commercially practicable solution in respect of a person who suffers because of defects in a building but is not able to obtain damages from the builder who is responsible for the defects for what the courts term pure economic loss. This must, of course, be done without upsetting the established principles of the need to show ‘special relationship of proximity’ between the plaintiff and the defendant and the need to show that the damages awarded are not considered too remote.

In the past, the Parliament in the UK had to intervene in consumer contracts where the doctrine of freedom of contract was held sacred by the judges who were apparently bound by precedents and/or oblivious to the reality of the parties' vast differences in their respective bargaining power to negotiate contracts based on 'pure consensus'. Perhaps it is time again for Parliament to rise to the occasion to intervene in the law of negligence.

SIGAPORE CASE STUDIES

Two Singapore cases are examined for the purpose of this paper. The first case is *Chia Kok Leong and another* v. *Prosperland Pte Ltd* [2005] 2 SLR 484 where the Singapore Court of Appeal was asked to decide whether a developer can claim against the architect substantial damages even though the developer has suffered no loss and the management corporation of the development has a direct legal remedy in tort against the architect.

The second case is *RSP Architects Planners & Engineers* v. *Ocean Front Pte Ltd and another appeal* [1996] 1 SLR 113 where the Singapore Court of Appeal was asked to decide whether a management corporation has a claim against the developers, whether in contract or in tort, for pure economic loss in the form of cost of repair or making good those defects complained of.

The *Prosperland* case

This case involved the construction of a condominium which was completed in August 1993. The respondent developer had engaged the appellant architect for the project. The developer had also engaged a contractor who was the first defendant in the case below but who did not appeal. In this type of development, the formation of a statutory management corporation (MC) is prescribed by the Singapore Land Titles (Strata) Act (Cap 158, 1988 Rev Ed) (now replaced by the Building Maintenance Strata Management Act). The MC becomes the proprietor of the common property of the condominium.

On 2 May 2002, the developer commenced an action against the builder for defective works comprising the de-bonding of tiles that formed the external façade of the building and damage to the glass blocks installed at the lobbies and stairways. In addition, the developer sued the architect for breach of contract in failing to exercise due care in the design and supervision of the project which resulted in the defective works.

At the time of the institution of the action, the developer was no longer the owner of the condominium. The individual units in the condominium were transferred to third parties. The common areas of the condominium became vested in the MC. The developer had not spent any money on repairs. The developer was also not sued by the MC in respect of the defects. The developer was placed under voluntary liquidation in December 2002.

In any event, the developer obtained a 10-year warranty from the builder and the supplier of the adhesives that were used in the external wall tile façade. There is evidence that the MC intended to carry out the repairs and it was also looking towards the developer for relief. The MC also expected the developer to carry out rectifications. Moreover, there is evidence that the developer intended to use the damages recovered for that purpose. The developers and the present owners are related (para. 58).

The Court of Appeal decided (at para. 45) that the present case fell within the narrow ground of the exception expounded in the *St Martins* case. This is because the legal black hole was not removed completely since the management corporation had a limited right to claim in tort against the builder and the architect. There was a deed of care given by the builder to the purchasers. Thus this cannot justify taking away of the contractual rights of the building employer under *The Albazero* exception.

The Court of Appeal decided (at para. 59) that the developer was, in principle, entitled to claim for substantial damages pursuant to the broad ground. It was held that, 'the basis on which a plaintiff is entitled to claim for substantial damages under the broad ground is that he did not receive what he bargained and paid for. It has nothing to do with ownership of the thing or property.'[4]

> Neither should the claim be dependent upon whether a third party can sue the party in default in tort. Why should the existence of such a right in a third party to claim in tort affect the contractual rights of the plaintiff? The only thing which the court should guard against is to ensure that the builder is not required to compensate twice over for the same damage.

The court added that the broad ground is probably more consistent with principle:

> 52 There is no reason why the employer's right to sue for his loss should be dependent on whether he is owner of the property or otherwise. The only problem that could arise, which is more apparent than real, is that the builder could be exposed to double liability. …The court ought not to deprive a party of his just contractual relief on account of perceived difficulty which could be easily surmounted.

It is to be noted that the broad ground does not require that repairs have already been carried out by the developer nor does it require an intention to do so before he is entitled to claim substantial damages (para. 57).

The *Ocean Front* case

This case also involved the construction of a condominium. In this case, the management corporation (MC), a creature of statute, was the plaintiff. It was constituted after the completion of the condominium. Before the constitution of the MC, the developer was given the statutory task of maintaining the common property of the condominium. Accordingly, the MC took over the management and administration of the condominium from the developers from 15 November 1987.

In May 1989, complaints were made by the MC to the developer in respect of the spalling of concrete in the ceilings of the car parks of the various blocks. Repairs were carried out by the developer but these did not resolve the problem. There was also insufficient drainage of some common areas because of a lack of sufficient gradient. This led to a collection of water at several lift lobbies on the buildings.

On 28 June 1991, the MC sued the developer claiming damages in respect of the alleged faulty construction of certain areas of the common property. The parties agreed to obtain the court's answer to the claim as a preliminary issue. The High Court decided in favour of the MC and the developer appealed.

At the Court of Appeal, the issue framed by the court was:

> Whether the management corporation has a claim against the developers, whether in contract or in tort, for pure economic loss in the form of cost of repair or making good those defects complained of.

The Court of Appeal decided to review all relevant cases from the whole of the Commonwealth and concluded:

> 63 From our examination of all these authorities, it seems to us that there is no single rule or set of rules for determining, first, whether a duty of care arise in a particular circumstance and, second, the scope of that duty. In *Governors of the Peabody Donation Fund* v. *Sir Lindsay Parkinson & Co Ltd* [1985] AC 210, at p.240, Lord Keith of Kinkel said:
>
> 'The true question in each case is whether the particular defendant owed to the particular plaintiff a duty of care having the scope which is contended for, and whether he was in breach of that duty with consequent loss to the plaintiff. A relationship of proximity in Lord Atkin's sense must exist before any duty of care can arise, but the scope of the duty must depend on all the circumstances of the case. … So in determining whether or not a duty of care of particular scope was incumbent upon a defendant it is material to take into consideration whether it was just and reasonable that it should be so.'

Having accepted that the answer lies in the circumstances of the case, the Court of Appeal proceeded to isolate the facts that formed the circumstances. The Court of Appeal then applied the principles set out in the *Junior Books* case to the facts identified above.

> 74 … we regard the following facts of crucial importance in determining that there is sufficient proximity between the developers and the management corporation which gives rise to the duty of care: (i) the management corporation was an entity conceived and created by the developers; (ii) the developers were the party who built and developed the condominium including the common property and undertook the obligations to construct it in a good and workmanlike manner and were alone responsible for such construction; (iii) after completion of the condominium the developers were the party solely responsible for the maintenance and upkeep of the common property; (iv) the management corporation as the successor of the developers took over the control, management and administration of the common property and has the obligations of upkeeping and maintaining the common property; (v) the performance of these obligations is very much dependent on the developers having exercised reasonable care in the construction of the common property; (vi) the developers obviously knew or ought to have known that if they were negligent in their construction of the common property the resulting defects would have to be made good by the management corporation. The relationship between the developers and management corporation is as close it could be short of actual privity of contract. …

Further, the Court of Appeal then applied the second stage of the *Anns* test by asking whether there is any reason to reject the duty of care established in the first stage of the *Anns* test.

> 75 We now turn to consider whether there is any policy consideration in negativing such duty of care. First, there is the question whether this would result in imposing liability 'in an indeterminate amount for an indeterminate time to an indeterminate class'. The amount recoverable is the cost of repair and making good the defects in the common property and in no way can it be said to be indeterminate. The class of persons is finite and definable. As for the duration, the time span is also not indeterminate, as the maximum period of time in which the developers can possibly be exposed to liability is limited by the Limitation Act (Cap 163): see s 24B. Secondly, there is also a related objection that recovery for economic loss would result in an indefinitely transmissible warranty. The common property has been and will continue to remain in the control and under the management of the management corporation. There is no question of any transmissible warranty to any other party.

Accordingly, the Court of Appeal allowed, in principle, the MC's claim against the developer in respect of pure economic loss as represented by the cost of repairs of defects found in the common property of the condominium.

OBSERVATION AND ANALYSIS

The *Prosperland* case

Since the principle relied upon in the *Prosperland* case is part of an exception to the general rule, its application should be strictly controlled and used sparingly. It is submitted that the immoveable property cases should be distinguished from the sale of goods cases and that the use of the exception be disallowed.

An important difference between *Prosperland* and *Dunlop* is that while the cause of the damage of the goods is traced back to the shipper and not the seller or manufacturer, there is no party who transports the immoveable property and more importantly, the party who is responsible for the damage is the developer under the sale and purchase contract of the immoveable property while the party who caused the damage is the 'manufacturer' or designer and builder in the case of immoveable property.

Another important difference arising from the first point would be that there is no issue regarding the lack of privity of contract to sue. Again, in comparison, whereas the buyer in *Dunlop* cannot sue the seller since the risk in the goods has passed from the seller to the buyer and further the buyer cannot sue the party who caused the damage, i.e. the shipper, since it is the seller who contracts with the shipper and not the buyer, the buyer in *Prosperland* has a contract with the party who is responsible for the inherent building defects since when the risk in the immoveable property transfers from developer to the buyer on the date of completion of the sale and purchase contract, the defects were already in existence in the immoveable property. In other words, the buyer in *Prosperland* did not suffer the problem of the lack of privity of contract as in the *Dunlop* case since the buyer's recourse would be against the developer.

Accordingly, it is open to the buyer in *Prosperland* to sue the developer claiming damages in respect of the defects in the building. The developer, in turn, would recover from the party that caused the defects, i.e. the builder and/or the designer(s). However, the usual practice in Singapore is for each developer to have a company incorporated for a project. Not long after the completion of the project, the said company would dissolve itself voluntarily thereby transferring the profits of that company to the holding company. This ensures that the said company is not available in the long run for any suits by the buyers.

Thus, the *Dunlop* exception should not be applied in *Prosperland,* indeed in all immoveable property cases since, as explained above, there is no issue of the lack of privity of contract to overcome. However, the buyer may not, for practical purposes, be able to recover compensation from the developer if it no longer exists.

The *Ocean Front* case

It can be seen from the evolution of the law of negligence, the courts are struggling to understand the nature of defects in a building in relation to the issue of remoteness of damage because of its classification as pure economic loss.

Unlike where there is a contractual relationship, a buyer cannot recover from a developer loss suffered in respect of building defects because of the defence of independent contractor that the developer is entitled to use when he points the accusing finger at the builder and/or designers for being legally responsible for the said defects. In the case of subsequent buyers, there is no contractual relationship with the developer. Consequently, such parties can only hope to recover compensation under the law of negligence.

The journey towards being successful in a pure economic loss claim requires the plaintiff to prove that there exists a special relationship of proximity. To this end, only the MC has met with limited success in Singapore. Thus far, the MC has been successful as against the developer and the architect in respect of defects in the common property. However, the position of the subsidiary proprietor in respect of building defects within the unit that belongs to the subsidiary proprietor as against the developer, builder and/or designers, whether as the first or subsequent buyer, has yet to be determined by a Singapore court.

RECOMMENDATION

It is with greatest respect to the Singapore Court of Appeal that it is submitted that the *Dunlop* exception should not be applied to an immoveable property case for the reasons given above. In any event, the position of the buyers in *Prosperland* remains uncertain since there is no mention that the developer remains accountable to them. It is also submitted that the position of the buyer in *Ocean Front* remains uncertain as the case applies to the MC and not to the buyer.

Therefore it is recommended that Parliament regulate the matter through the existing legal framework. According to the Housing Developers (Project Accounts) Rules, a developer may collect money from buyers as the construction of the works progresses and deposit the moneys collected in a designated project account in a bank. Such moneys may be withdrawn progressively for making payments as prescribed by the Rules as certified by the Architect. Upon the completion of the works, the balance of the moneys in the project account may be withdrawn by the developer, presumably as its profits.

It is recommended that instead of allowing a complete withdrawal of the moneys in the project account, a significant percentage of the moneys left in the project account can only be withdrawn upon the expiry of the limitation period relevant to latent defects, i.e. a period of 15 years after the completion of the project. The provision for the 15-year period was adopted from the UK Latent Damage Act 1986. The moneys in the project account may be used to meet the claims by both the MC and the subsidiary proprietors in respect of defects in the building. Perhaps the money could be used to extend the performance bond given by the builder with the amount payable enhanced. Any such claim must be supported by a building surveyor's report. However, to preserve the right to claim, the MC and each subsidiary proprietor must conduct an annual building survey that must be filed with the developer. This ensures that there is no double claiming of the same defect.

Alternatively, parties may not wish to submit the annual building surveyor's report and would then be excluded from any right to claim from the project account. Incidental to this scheme would be the benefit of knowing whether the property is free from serious structural defects if annual building surveys are carried out.

CONCLUSION

The law is not perfect. It has allowed an exception to a rule in the law of contract to gain unnecessary importance. More importantly, it has allowed a cross-application of the exception principle relating to the recovery of damages from sale of goods cases that requires transport to sale of immoveable property that requires no transport without a clear and proper analysis of the contractual relationships of all the parties involved. However, it has been often said that bad law is nevertheless the law until it is overruled.

In the law of negligence, nothing is more disconcerting than seeing the great legal minds struggle with the formulation of a legal principle that requires an understanding of a non-legal concept, that is, how to deal with pure economic loss associated with building defects.

The real issue is perhaps what Lord Millet said in *Panatown*, that of ensuring that the damages are paid to the right party. This objective is just as applicable in a contractual dispute in *Panatown* as it would be in any tortious dispute. The question would be, as always, how much longer must the parties wait for the courts to give a commercially acceptable solution.

As Parliament has reshaped the law of contract in consumer contracts involving goods, Parliament can once again reshape the law relating to building defects to ensure that damages are paid to the right party. This route would always be faster than that taken by the courts but only if both started at the same time. However, Parliament must have the necessary political will and motivation and perhaps even simple awareness that the problem exists.

NOTES

1. See paragraph 27 of *Chia Kok Leong and another* v. *Prosperland Pte Ltd* [2005] SGCA 12; [2005] 2 SLR 484.
2. See paragraph 13 of *Chia Kok Leong and another* v. *Prosperland Pte Ltd* [2005] SGCA 12; [2005] 2 SLR 484.
3. See paragraph 21 of *Chia Kok Leong and another* v. *Prosperland Pte Ltd* [2005] SGCA 12; [2005] 2 SLR 484.
4. See paragraph 53.

REFERENCES

Construction Industry Board (1997) *Report by Working Group 10 of the Construction Industry Board on liability and latent defects insurance*. London: Thomas Telford.

Duncan Wallace, I N (2004) *Hudson's building and engineering contract: including the duties and liabilities of architects, engineers and surveyors*. 11ed. and 1st Supp. London: Sweet & Maxwell.

Knocke, J (1993) *Post-construction liability and insurance*. London: E & FN Spon.

Lavers, A (1999) *Case studies in post-construction liability and insurance*. London: E & FN Spon.

Lavers, A and Keeping, M (1995) Collateral warranties in property development: chimera not panacea. *Property Review*.

May, A (1995) *Keating on building contracts*. 6ed. London: Sweet & Maxwell.

Turner, G (1995) The Latham Committee: latent defects liability and 'build' proposals and insurance considerations for commercial, retail and industrial property. *Structural Survey*, **13**(4), 13–15.

JAPANESE BIDDING PATTERNS: A STATISTICAL APPROACH

Jun Iwamatsu,[1] Kazuyoshi Endo[2] and Tetsukazu Akiyama[3]

[1]*Research Institute on Building Cost (RIBC), 3-25-33 Nishi-Shinbashi, Minato-ku ,Tokyo, 105-0003, Japan*
[2]*Department of Architecture, Kogakuin University, Tokyo 163-8677, Japan*
[3]*Department of Architecture, Toyo University, Saitama 350-8585, Japan*

In the Japanese construction sector where the bidding system has been recently reformed, the data of the tender results in areas of public construction works and/or consultancy services are now being made open, enabling objective analysis of such data from various viewpoints. In this research, such open data of a nationwide coverage in the last two years or so has been collected comprehensively for academic analysis using some statistical methods. The main point of this research is to gain a rough grasp of the tendering activities in the Japanese construction contractors and/or consultants. There are two methods used in the analysis: (1) analysis by focusing on each individual tendering action and (2) analysis by focusing on each individual enterprise of the three selected sectors. In addition, public investments are seen to be decreasing sharply and the jurisdictional control to bid-rigging practices is being strengthened. The analysis of these data clarifies the tendency that severe competition among the bidders taking place and bidders resorting to price-dumping practices, which is becoming remarkable among the concerned part of the industry.

Keywords: competitiveness, bidding, statistical analysis, construction company, consultant.

INTRODUCTION

Background of research

The construction industry of Japan has been confronting a structural recession, which had never been experienced in the past. Construction investment has fallen to a level of some 50 trillion yen now from about 80 trillion yen in the 1990s.

Under the current Japanese government finance crisis, it is evident that the minus situation of public works expenditures will continue (Figure 1). Although the number of construction licence registrations on the part of contractors is decreasing slightly from a peak level, there still are 500,000 contractors in the shrinking market. That is, construction industry is being thrown into a state of excessive competition. Furthermore, it is in a situation where severe compliance is called for, by the enforcement of the Act for Promoting Proper Tendering and Contracting for Public Works (enforced in April 2001), and the revised enforcement of Antimonopoly Law (January 2006). So-called "bid rigging", widely practiced in the public-works sector, is becoming more severely controlled.

[1] iwamatsu@ribc.or.jp

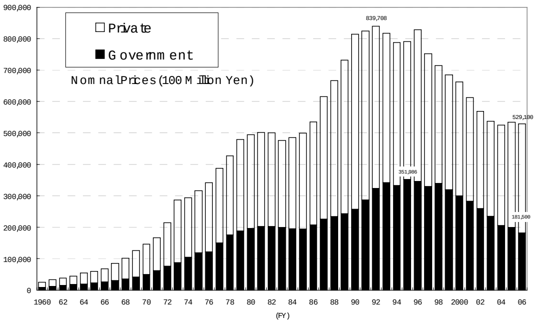


Figure 1: Trend of the amount of construction investments in Japan (nominal value) (Source: *Construction Investment Prospect,* MLIT)

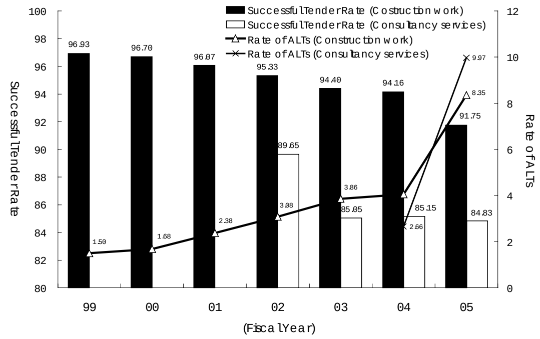


Figure 2: Transition of average successful tender rate of construction and consultancy at MLIT (Source: *Data of Construction Contracts*, MLIT (including pre-MLIT period, i.e. Ministry of Construction). Construction of seaports and airports is excluded)

Under such a situation, a price-dumping tendency is becoming rampant in the competitive tendering or bidding. Figure 2 shows transition of the successful tender rate of construction orders and related consultancy services at MLIT (Ministry of Land, Infrastructure and Transport, Government of Japan) as this ministry performs much of the public construction investment in Japan. A successful tender rate is defined as the rate of the successful tender price compared to the ceiling price (a "ceiling price" is the pre-set amount of cost-of-construction as reasonably predicted by owner-side engineers on basis of the provisions of the Public Account (Financial) Law (enacted by the Japanese government early in 1889). Unlike in other countries, there is a provision where such a pre-estimated amount should stay under a certain ceiling, leading to a rule that the successful tender price should not exceed the ceiling price). The successful tender rate of the construction, which was about 97% on the average in the 1999 fiscal year, fell to a little less than 92% in the 2005 fiscal year. Moreover, the percentage of low-priced tenders is growing and such low-priced tendering was found in a little less than 10% of all tenders in the 2005 fiscal year on both construction works and consultancy services. This is regarded as a questionable tendency from such viewpoints of ensuring construction quality, sound growth of the construction industry, etc., and is being brought up as a political issue. (As for abnormally low tenders, related laws and provisions are now defined under the Public Account Law. That is, officials specializing in related contracts are to decide "the investigation-based prices" to stay between 66.6% (2/3) through 80.0% of the ceiling prices as widely accepted in Japan. In the case of abnormally low tenders, there exists an established procedure to conduct contractor hearings as such. But, in the past, even such low tenders were almost freely processed in the absence of any criteria to discretely determine dumping prices as such with which abnormally low tenders could have been duly rejected. The enforcement in December 2006 of an "applied criterion", however, has led to the powerful action to exclude such price dumping.)

Enforcement of APPTCPW and official announcement of tender results

The Act for Promoting Proper Tendering and Contracting for Public Works (APPTCPW) was enacted as of 27th November 2000 in Japan. The purposes of this Act are to secure the general public's trust toward public works and to promote the sound development of the construction industry that contracts public works commissioned by the Central Government, quasi-governmental agencies and local governments through the (1) establishment of requirements that form the foundation of proper tendering and contracting, (2) public announcement of relevant information, and so on.

Due to the Act, the Regional Construction Bureau of MLIT and several other agencies have recently provided the information about tender results to the public. The tender results are classified into two categories: construction works and consultancy concerning public works. In this research, the authors were able to obtain about 170 thousands tendering information of FY 2005-2006 in each category. The data seems to cover almost all the major tenders in each of those bureaus and agencies. The authors statistically analysed the data.

About the data for analysis

In this research, tender result information was obtained through the Internet (the source of the analytical data was: the website (http://ogb/go.jp/choutatu/htm) for each of the entities listed thereon or that (http://www.ppi.go.jp) of the PPI (Public Works Procurement Information Service) as an antenna window of JACIC (the Japan Construction Information Center). In the last two years, such data has been collectively announced in MS Excel format on MLIT's website (www.mlit.go.jp/chotatsu/kekka/kekka.html). All data, thus collected in this study, has been analysed and rearranged solely by the staff of the Endo Lab. of the Kogakuin University, where the data was mostly converted into SPSS for Windows). It was in autumn of 2006 when we obtained all the tender result data of 10 order organizations throughout the country, as shown in Figure 3 (the Okinawa entity is under direct administration of the Cabinet Office of the Japanese government, while nine other entities are under MLIT administration). Tender results information is roughly divided into two: construction works and consultancy services. Excepting the local Okinawa data, it encompasses the period of about 18 months covering the contracts from April 2005 through August 2006. The data was obtained under the situation of the excessive competition widely seen in the construction industry, as mentioned at the start of this paper. Specific figures of the data are shown in Table 1.

Table 1: Outline of the analysed data

By ordering offices	Construction works		Consultancy services	
	No. of cases of construction	**No. of tenders**	**No. of cases of consultancy**	**No. of tenders**
01 Hokkaido Regional Development Bureau	3,871	33,005	4,427	44,998
02 Tohoku Regional Development Bureau	1,971	20,885	1,538	16,316
03 Kanto Regional Development Bureau	2,674	27,647	2,194	25,919
04 Chubu Regional Development Bureau	1,623	14,070	1,208	13,533
05 Hokuriku Regional Development Bureau	1,235	10,807	969	10,869
06 Kinki Regional Development Bureau	1,724	15,284	1,628	16,455
07 Chugoku Regional Development Bureau	1,460	12,719	1,347	14,263
08 Shikoku Regional Development Bureau	844	7,671	736	7,869
09 Kyushu Regional Development Bureau	2,552	26,713	1,993	20,485
10 Okinawa General Bureau	312	3,188	434	2,469
Grand total	18,266	171,989	16,474	173,176

The period of data collection was April 2005 through August 2006, except "10. Okinawa General Bureau," to include: construction – March 2004 through August 2006, and consultancy – January 2004 through August 2006, only.

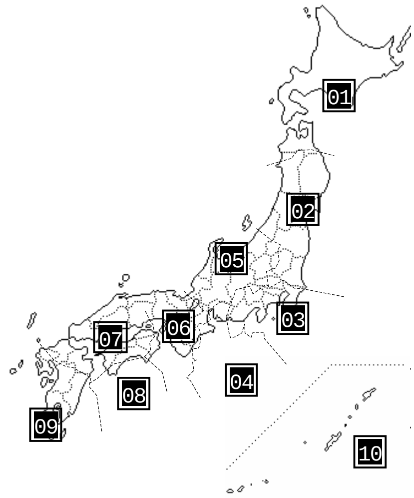


Figure 3: Jurisdictional area (outline)

The specific items of information in the table are: tendering project names, ordering departments in the ministry, specific types of construction projects or consultancy services, the number of tendering times of each bidder (up to three times), ceiling prices, tenderers' names, tendered prices, names of successful tenderers, final tender prices, overall evaluation (given or not given), overall evaluation scores, etc.

As for the construction work data, its coverage was 68.5% of the total monetary value, as derived from the result of our calculation of its ratios against the total value of monthly order prices (which was acquired from the Current Survey on Orders Received). The remainder is presumed to represent private tenders (excepted for analysis reasons) without competition, and orders from other ministries and government offices (i.e. Ministry of Agriculture, Forestry, and Fishery etc.). Since it is a high coverage of data, it should be able to command a whole view of the situation of the whole, which has occurred by order construction work of from a nationwide perspective, and is useful for generalization of an analysis result. (As for the construction work data, the data for the 10 "tendered" cases were analysed in this study, but the remaining 696 "private contract" cases without tender entries were excluded from the analysis. The latter group represents small-scale construction works, with their average contract amount being approximately 112 million yen. Incidentally, the grand total price happens to be some 76,786 million yen or and the overall data coverage can be calculated at 71.4%.)

The direction of analysis

The main point of this research is to enable a rough grasp of the tendering activities in the Japanese construction contractors and/or consultants, while there are two methods used in this analysis: (1) analysis by focusing on each individual tendering action and 2) analysis by focusing on each individual contractor and/or consultant. Through (1), the situation of competitions, according to the types of work and ordering organization, would be expected to be understood based on the number of bidders (tenderers), successful tendering percentage and tendering price distribution. Through (2), it is possible to analyse the pattern of tendering behaviours by defining each contractor's and/or consultant's competitive capacities.

ANALYSIS OF INDIVIDUAL TENDERS

First, analysis is focused on each case of tendering behaviours. Specifically, we analyse the data using such indices as the number of participants to tendering, variation of tendering prices, and successful tender rates. Further, we see the actual situation of the "Performance-based Evaluation Contract with Technical Proposal".

The number of bidders (tenderers)
In Japan, the designated competitive bidding has been popular ever since the overall revision of the Public Account Law in 1900. It is up to the intention of an order organization to determine the maximum number of tendering participants in the designated competitive bidding system.

A notification by the Ministry of Construction once defined the number of tendering persons to be ten in the designated competitive bidding system. Despite the later abolition of that regulation, the system of competition by ten persons has become customary in many cases. In Figure 4, the histogram respectively shows the result of the total number of participants in the first tendering. Figure 4 shows the distribution for the construction works, somewhat spreading on both sides, with the highest participation by ten persons. On the other hand, the distribution for the consultancy services is inclined only toward ten persons.

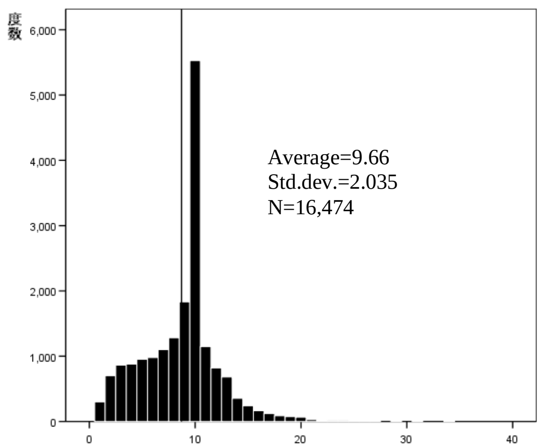


Figure 4a: Histogram of the number of tender participants (construction works)

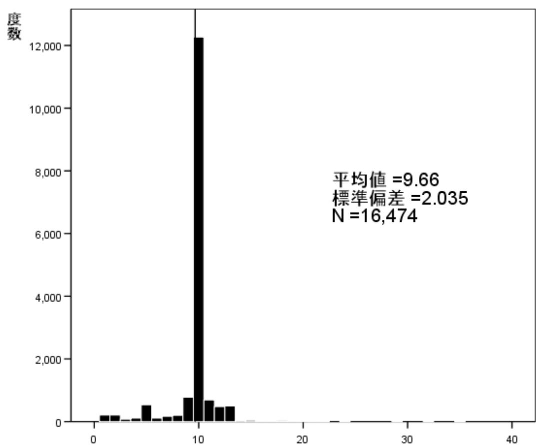


Figure 4b: Histogram of the number of tender participants (consultancy services)

Coefficient of variation of a bidding value
As mentioned above, tendering is performed by more than two competitors. In order to statistically find differences among those competitors, an index is created showing the grade of the variation of bid prices in a tender. The general index in that case is a coefficient of variation of such bidding values. A coefficient of variation is calculated by dividing the standard deviation of the bid value in each tender by the average value as the denominator. The smaller the numerical value is, the less the variation in the tender price.

Table 2 shows the statistical value of tender situation according to the type of works and tender systems. The average value of coefficients of variation of tender value of all construction work is 5.80, and that of consultancy services is 9.30, so it is clear that the latter somewhat varies. The ceiling price of consultancy services will be hardly presumed. Such difficulty can probably be related to the smallness of the successful bid rate, which is described below. In past research by the authors using the construction work data of the same MLIT (MLIT in 2002 used to be called "Ministry of Construction") for 1998 to 1999 (Akiyama *et al*. 2002), the average value was 2.9. In addition, Skitmore (1988) who rearranged many tender-related research papers, the values were spreading from 5.0 to 8.4. In the past, the bidding prices for public works in Japan had small coefficients of variation, showing close coherence. Nowadays, however, variations are showing up in the same range as the research findings in foreign countries. The reason for this rather rapid change would be because the competitive environment in the Japanese sector of tendering is becoming severer. This phenomenon is also reflected in the declining pace of successful bid rates as shown below. It can be assumed from such a change that the Japanese public construction market is changing to a new environment where not only bid-rigging practices are being suppressed but also the genuine mode of price competition is being encouraged.

The changing situation as mentioned above can be verified through calculation of the coefficients of variation of data according to specific types of construction work. In Table 2, the values of various indicators about tender situation are statistically summarized. Having reviewed the data a bit more finely according to the types of construction works, we can see differences in the derived value of the coefficients of variation in related tender values. The reasons considered are that (1) the competitive situation is not equal among the types of work; and (2) the differences arise from the gap of accuracy of the construction cost prediction among them, depending on various technological reasons, and so forth.

Table 2a: Statistical value of tender situation according to the type of works and tender systems (construction work)

		No. of valid data	1st tender				Average successful tender (1000 yen)	Average successful tender rate (%)
			No. of tenders	Average ratio to estimated price	Average no. of tender participants	Coef. of variation of tender value		
Tender Systems	1.Designated comp. bidding	14,339	131,511	102.06	9.16	5.65	69,568	92.24
	2.Open and comp. bidding	2,339	17,894	97.56	7.07	6.07	173,976	90.25
	3.Limited tendering	1	30	100.61	1.90	3.69	42,722	95.26
	4.Others	1,286	9,795	98.33	7.13	6.95	258,628	89.23
Type of Works (Outline)	1.Architectural works	871	7,239	**110.21**	8.26	**10.71**	63,719	89.39
	2.Civil engineering works	14,247	130,124	100.03	9.04	4.51	106,448	92.09
	3.Equipment works	2,543	18,986	107.15	7.00	**11.12**	58,200	91.02
	4.Others and unknown	304	2,881	99.38	9.59	7.28	168,520	88.22
Type of Works (Detailed)	01.General civil engineering	6,385	59,557	100.12	9.28	4.11	149,765	92.35
	02.Asphalt paving	1,505	15,344	99.37	10.17	2.87	123,628	94.11
	03.Steel bridge-top construction	205	1,816	**83.80**	8.07	**13.02**	213,070	**74.44**
	04.Landscaping & gardening	626	6,513	99.37	10.39	4.82	30,421	90.59
	05.Building construction	850	7,057	**110.24**	8.25	**10.80**	64,098	89.36
	06.Wooden structure building	10	103	106.93	10.30	7.94	29,543	87.38
	07.Electrical equipment	708	6,639	103.56	9.22	6.02	62,041	91.03
	08.Heating air condition	240	2,201	105.71	8.98	8.65	66,450	89.64
	09.Cement/concrete paving	35	301	102.40	8.60	3.88	165,314	**95.28**
	10.Pre-stressed concrete work	241	2,065	96.75	8.50	6.11	248,720	88.16
	11.Slope conducting	180	1,685	99.52	9.31	5.88	66,907	89.61
	12.Painting	419	4,827	95.87	11.44	6.11	24,939	85.84
	13.Maintenance & repair	4,523	36,967	101.73	8.03	4.88	46,185	92.97
	14.River dredging work	39	296	100.28	7.22	5.37	244,291	91.37
	15.Grouting work	50	423	101.93	8.46	3.65	68,302	**95.16**
	16.Pile driving construction	5	54	102.29	10.80	6.17	121,900	92.06
	17.Well drilling construction	34	276	104.41	7.89	9.16	38,823	91.05
	18.Prefabricated building	11	79	**112.40**	7.18	6.24	65,409	93.73
	19.Machine & equipment inst.	593	4,010	104.57	6.18	**11.59**	69,337	89.64
	20.Telecommunication equip.	854	5,097	**112.87**	**5.41**	**14.38**	48,171	92.44
	21.Electrical receiving	148	1,039	**114.99**	6.66	**18.92**	41,404	90.27
	27.Others and unknown	304	2,881	99.38	9.59	7.28	168,520	88.22
Grand total		17,965	159,230	101.33	8.71	5.80	98,310	91.74

Table 2b: Statistical value of tender situation according to the type of services and tender systems (consultancy services)

		No. of valid data	1st tender: No. of tenders	1st tender: Average ratio to estimated price	1st tender: Average no. of tender participants	1st tender: Coef. of variation of tender value	Average successful tender (1000 yen)	Average successful tender rate (%)
Tender Systems	1.Designated comp. bidding	16,250	159,141	103.31	9.77	9.30	11,223	86.61
	2.Limited tendering	0	205	97.41	1.00	.	27,410	97.34
	3.Others	16	140	95.13	7.78	8.61	6,138	88.35
Type of Consultancy Services	1.Survey consultancy	3,846	37,759	100.60	9.78	8.43	9,669	87.20
	2.Geological survey consul.	1,363	13,825	98.52	10.12	6.52	14,189	87.74
	3.Civil design consultancy	7,626	74,480	102.24	9.74	9.35	12,867	86.41
	4.Architectural design consul.	769	6,968	**129.11**	9.05	**25.30**	3,666	**79.07**
	5.Compensation consultancy	2,431	24,119	105.98	9.91	6.46	9,205	88.47
	6.Others and unknown	231	2,335	104.14	5.57	**15.31**	18,444	89.01
	Ground total	16,266	159,486	103.30	9.66	9.30	11,407	86.73

(Note) "No. of valid data" is taken from successful bid prices. That is, it should be noted that the valid numbers of each indicator in this table differ respectively. Data for tender decliners was not included in "No. of tenders". The numbers with bold-faced type in the table represent unique values.

Successful bid rates

A successful bid rate is a ratio of the contract price to owner's ceiling price. This index is commonly used in Japan as the indicator showing the competitiveness of concerned tenders. However, although this indicator is partial and of a single dimension, there is an injurious effect of its having been the over-emphasized topic of discussions. For example, the Japan Citizen's Ombudsman Association (JCOA) has created a criterion to judge existence of bid rigging in one client if the average successful bid rate exceeds 95% (this council names their criteria as "Doubt-degrees of bid-rigging scandal", releasing the ranking data according to the specific dimensions about the construction work-orders which all local and municipal issue every year). However, there is no logical basis in this judgment position. But, such ceiling prices are not necessarily fair and non-vulnerable, in that a ceiling price with an upper limit restraint is created by the engineer of a client, and that it is set up based on the prediction quantity from the construction document based on their estimation criteria, and also on the ceiling prices of materials, special construction expenses and so on, as published by some price research institutes. Here, in light of such situation, the authors would hereby describe the actual Japanese tender behaviours as can be observed from the indicator of successful bid rates revealing a meaningful indicator.

As shown in Table 2, the average successful bid rate of construction works is 91.74% and that of consultancy services 86.73%. Moreover, as seen from the overall shape of the distribution, consultancy services have a little more spreading distribution.

The specific data of successful bid rates according to type of construction works is also shown in Table 2 above. From the data of construction work, it is clear that the successful bid rates of road paving work, such as "09 Cement/concrete paving" and "02 Asphalt paving", are slightly high, and "03 Steel bridge-top construction" is the lowest. "01 General civil engineering" and "05 Building construction" being performed under many orders show in-between values. The histogram of successful bid rates is illustrated according to these notable construction work types (as shown on the right side of Figure 5. And, the histogram of the ratios resulting from division of the first-time tender value by ceiling prices is also shown on the left side of Figure 5.

Since the clients are to determine ceiling prices, each as an upper limit price, the rates shown here should serve as the ratio to clarify the relative position of each tender value. As these graphs share the same x-axis scale, so the comparison of distribution value. As these graphs share the same x-axis scale, so the comparison of distribution among the construction work types is enabled. (The ratios here are also used officially as data describing MLIT's tender business situation at http://www.mlit.go.jp/chotatsu/contractsystem/getuji.html in Japanese only.)

Examining these two shapes of distribution should clarify the specific features of the data for every type of construction works. In the distribution of tender values, "01 General civil engineering" and "02 Asphalt paving" are represented in a beautiful normal distribution near the 100% threshold (that is, showing the same amount as the ceiling price). And the successful bid rates are densely crowded around the comparatively high portion. Also in "03 Steel bridge-top structure construction", the distribution of tender values appear as inclined toward the low portion, and so are many values of successful bid rates. This will clarify the fact that in "03 Steel bridge-top construction", the market competition by abnormally low tenders (ALTs) is intense. And in "05 Building construction", the average percentage of tender value ratios is 110.2 with the distribution rather distorted by pulling down a little to the right side. Meanwhile, there also exists a portion of comparatively low rates of successful bids. This means that this is a severe area of competition on the part of the bidders of this type of construction work in correctly setting the bid prices. One of the reasons for this could be that the system of estimation is comparatively complicated and, so, it is difficult to estimate correctly in building construction works.

ANALYSIS OF THE CORPORATE BEHAVIORS BY CONSTRUCTION SECTORS

Extraction of the related sectors

We will particularly analyse the tender behaviours of construction enterprises participating en masse in competitive bids. Rather than the consultancy service data, construction work data has been chosen, for convenience' sake, to be analysed. In this research, three peculiar sectors (industry) were extracted by the following three sectors, with data to be analysed in such terms as the aggregation by the type of construction work, data searching by particular names of enterprise, etc. The data has been further selected on the condition that the date reflects the offering of five or more tenders and at least one successful bid, for the firms to be extracted within each of the three sectors (extracted on the same condition as adopted by Drew *et al.* 1993):

1. The bridge-building sector (33 companies) – these companies were extracted from the sector list in which the surcharge orders of payment issued by the Fair Trade Commission pursuant to certain bid-rigging affairs. Medium- and large-scale companies are included.
2. The road paving sector (84 companies) – companies evidently constructing roads were extracted (i.e. firm names containing the word "road" was picked up). Small through large-scale firms were included.
3. The sector of major general contractors (47 companies) – the top 50-company list of the construction industry sales data, based on some trade paper surveys, is used, and companies with achievements shown in this data are extracted. All firm represent major corporations only.

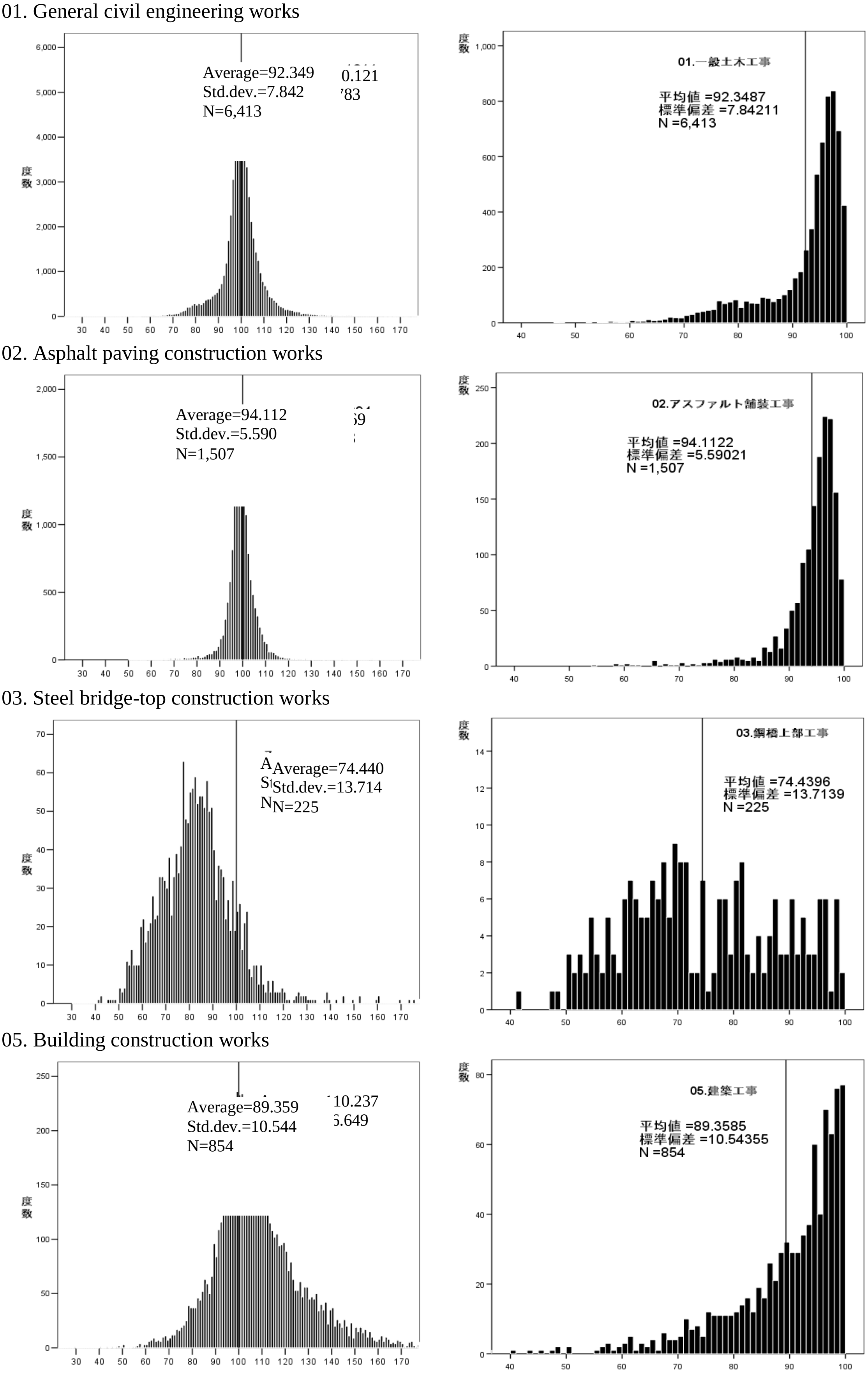


Figure 5: Histogram of ratios as the result of dividing the first-time tender value by estimated price (left side) and histogram of successful bid rates of some construction work types (right side)

Table 3: Outline of corporate behaviour data of the three sectors of construction industry

	Sector 1 Bridge-building	**Sector 2 Road repairing**	**Sector 3 Major GC**
Total no. of companies.	33	84	47
Aggregate total no. of tenders	1,522	8,387	3,258
Aggregate total no. of successful tenders	159	826	381
Average successful bid (1000 yen)	235,221	148,614	412,868
Average successful bid rate (%)	74.65	94.86	90.57
Standard deviation of above value	17.03	4.86	9.40
Average value of average competitiveness (the 1st time)	21.96	5.79	10.26
Average value of the standard deviation	19.44	6.36	13.13

(Note) These analytical data represent a total aggregation, in which number of “declined tenders” is not included.

Table 3 outlines the result of an analysis of corporate behaviours, as observed from the extracted data. Here, the word "competitiveness," as used in this analysis with each tender (by noting each company’s 1st tender only), is defined in the following equation:

Competitiveness = (Bidding price minus Contract price) / Contract price x100

The "Average Competitiveness" in Table 3 means an arithmetic average of competitiveness in all the tenders from each enterprise, and the Average Value means the arithmetic average of the average competitiveness values of two or more enterprises.

Bridge-building sector being shaken up upon disclosure of bid-rigging affairs (Sector 1)

In the steel bridge building sector whose main clientele is MLIT's Regional Development Bureau etc., there were two bid-rigging specialized organizations called 1_K-kai (old-Koyokai; 17 companies are members, a forerunner group of makers) and 2) A-kai (old-Azumakai; 30 companies are members, a late-coming group of makers). It became publicly clear in October 2004, as the result of an on-the-spot inspection conducted by the governmental Fair Trade Commission in October 2004, that these 47 companies of the two groups had been repeating bid-rigging practices (refer to http://ja.wikipedia.org/wiki in Japanese only).

This incident has resulted in the dispersal of the bid-rigging organizations, with some companies having had to withdraw from bridge building. Such confusion also affected the ordering side of the bridge building. In FY 2005, the order number of cases and the amount of order have fallen greatly, and this sector of industry has to face a severer competitive environment. In these study data, the situation surrounding about 33 companies after the incident disclosure is acquired. Among the 44 companies for which the Fair Trade Commission had issued the surcharge order of payment in March 2006, 11 companies without a fixed number of tender achievements were removed from the study for the reasons of their withdrawal from the market etc.

Road pavement sector of construction industry (Sector 2)

Road investment occupies a big pie of Japan's civil engineering-works investment. Sector 2 includes companies who mainly engage in road paving work. Since 83 companies included in this data actually succeeded in receiving orders for the nation’s public work, they are comparatively large companies. Since road paving is a type of work that requires special technologies; business superiority is enjoyed only by the companies belonging to this sector.

The sector of major general contractors (Sector 3)

The top 50 companies in construction sales were extracted; this group represents Japanese construction industry. Many engineers skilled in various technical fields are employed by these firms, covering a wide range of construction works and enabling them to participate in the tendering practice. They tend to be more involved in comparatively large-scaled construction work in monetary terms as shown also in Table 3.

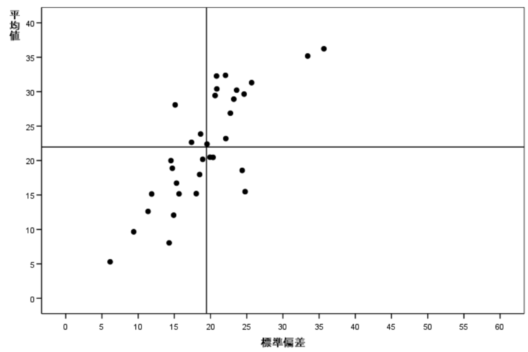
Comparative analysis of the three sectors using competitiveness indicators

The tendering behaviour of each enterprise as a member in each of the three sectors is plotted to the scatter diagram using competitiveness indicators as illustrated above (Figure 6). The vertical axis of the figure is the average value of competitiveness obtained from the accumulated tender result data of each enterprise, and the horizontal axis is the standard deviation of the value. It reflects that the closer a vertical axis is to the zero position of the chart, the more powerful the competitiveness is, and that the horizontal axis shows it being in a stable position.

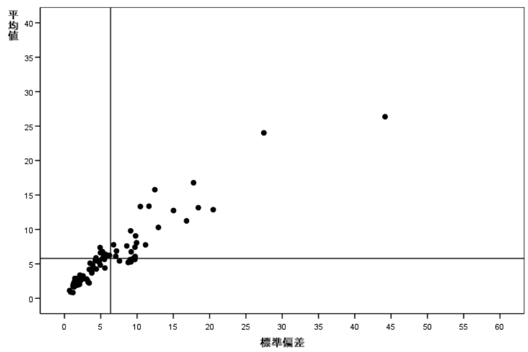
Classifying each sector's data of both axes with the arithmetic average values, the chart can be divided into four quadrants within each sector. Companies belonging to the first quadrant are companies characterized as "silly." Similarly, those in the second quadrant are named as "non-serious", the third quadrant as "sensible", and the fourth quadrant as "suicidal." These classification names and the analytic method used are based on Drew *et al*. (1993).

Figure 6 is plotted on the same scale for the three Sectors, enabling straight comparison with each other. In Sector 1 (bridge building), both average competitiveness and its standard deviation show high values and indicators are far from the zero position on the graph. Since Sector 1 is known to have rushed into severe dumping competition caused by the incident of bid-rigging exposure, this graph matches with such situation. Conversely, Sector 2 (road pavement) turns out to be closest to the graph's axis-zero position, and their competition is severe by a narrow margin. Sector 3 (general contractors) sits in between Sectors 1 and 2.

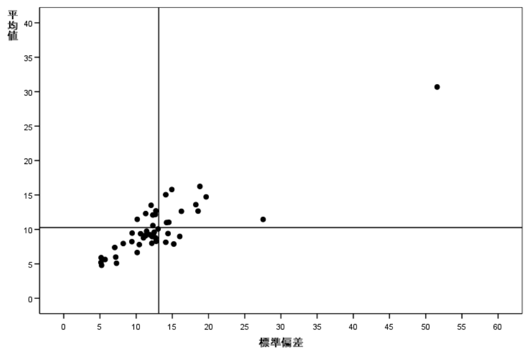
(1) The bridge building sector of industry



(2) The road pavement sector of industry



(3) The major contractor sector of industry



Legend:

Average	(ii)non-serious	(i)silly
	(iii)sensible	(iv)suicidal
	Standard deviation	

Figure 6: Company typology within each sector of industry reflecting average competitiveness and its standard deviation (the average line value of in each of above shown figures is shown in Table 3) (Cf. Drew *et al*. 1993)

Drew *et al*. (1993) analysed the data obtained from the housing industry of Hong Kong. They reported that its average competitiveness was 14.13 and its standard deviation was 13.79, and their indicators appear a little less distant from the axis-zero position, as compared with Sector 1 in this analysis. Meanwhile, Akiyama *et al*. (2002) etc., dealt with the similar situation of 118 companies by using the tender data of MLIT for the years 1998 through 1999, clarifying that their average competitiveness was 4.24 and the Standard deviation at 4.33. This means that they are almost the same as in Sector 2's case in this analysis. Since many of the 118 companies are major general contractors, these present-time values, if re-estimated now (i.e. 7 to 8 years thereafter), should be a little higher. Therefore, it can be concluded that what was once a competition with narrow margins is changing toward a severer competition with a recognizable variation at this moment.

As stated in the beginning, Japanese construction business has faced a comprehensive scale of reducing construction investments, leading to a more competitive market environment. Therefore, it can be conclusively said that the average competitiveness and its standard deviation values are leaving further from the axis-zero point in this analysis. This should also mean that the construction enterprise in present-day Japan is undergoing considerable differentiation in their competitive environments depending on what sectors the individual companies belong to.

CONCLUSION

This paper widely analyses the competitive environment surrounding the construction tender business in Japan using the published data on tender results in the construction industry. It also included past cases of authors' analysis as well as the data of some precedent researches so far made outside Japan. Therefore, this paper should clarify some specific characteristics of Japanese construction industry and related ongoing changes. However, since this study is still in process in that the "consultancy services" for the tendering entities, for instance, has not been covered yet, and that authors intend to pursue this aspect in future research. Furthermore, since more up-to-date data of accessible tender results keeps being accumulated, the authors will continuously monitor such up-to-date information for our study.

REFERENCES

Akiyama, T, Iwamatsu, J and Endo, K (2002) Bidding Strategies in Japanese Construction Projects. *In: CIB W55&W65 Joint Conference in Ohio, USA, Proceedings*, October, 982–99.

Drew, D and Skitmore, M (1997) The effect of contract type and size on competitiveness in bidding. *Construction Management and Economics*, **15**(5), 469–89.

Drew, D, Skitmore, M and Lo, H P (1993) Competitiveness in bidding: analysing the influence of competitors. *In: CIB W-65 Trinidad W.I., September 1993, Proceedings*, 417–26.

Skitmore, M (1988) The distribution of construction project bids (fundamental research in bidding for estimating). *In: CIB W-55 Haifa, Israel, Proceedings*, 171–83.

SOME NEGLECTED VARIABLES IN CONSTRUCTION MANAGEMENT RESEARCH CONTRIBUTING TO A COMPETITIVE ADVANTAGE RESEARCH APPROACH

Vernon Ireland[1]

[1]*Education Centre for Innovation and Commercialisation, The University of Adelaide, Adelaide, SA, 5005, Australia*

The purpose of the research was to identify variables or concepts which have had inadequate attention by construction researchers and practitioners, these being: CMMI, Enterprise architecture, Entrepreneurship, Operational Excellence rather than sustained competitive advantage, PMBOK, Portfolio, PRINCE2, Requirements and Vision. All appear to have relevance in construction.
A second purpose was to examine the relationship between the three types or levels of variables or concepts: external competitive strategy of a firm, the business environment in which the firm operates and the internal strategies chosen by the firm to achieve the external competitive strategy. Case studies were conducted on a group of mostly non-construction firms operating in a technology environment.
The methodology used included a major survey questionnaire and the use of principal components analysis to clarify variables. Correlations were then demonstrated between the three groups of variables.
Minimising cost within a niche and minimising time of delivery, segmenting the market and fit, were shown to be key competitive strategies. All internal strategies examined supported at least one external objective.

Keywords: business strategy, CMMI, enterprise architecture, entrepreneurship, requirements.

INTRODUCTION

Competitive strategy of firms has always been important and is becoming more so with globalisation. Construction research and practice can benefit from examining other disciplines which have similarities.

The research had two purposes:

1. Outline a number of concepts or variables which construction researchers could investigate more thoroughly, which are relevant in other areas of technology business and management, but which appear to have received little consideration in construction management research and practice;

2. More formally explore the relationships between the three classes of variables, these being the competitive strategy of the firm, the business environment in which the firm operates and the internal strategies which facilitate achievement of the external competitive strategy.

[1] vernon.ireland@adelaide.edu.au

With regard to the first objective, construction practitioners could benefit from greater awareness of these approaches in other industries and trial them in construction to assess their suitability.

With regard to the second objective, consideration of the approach of recognising these three levels of variables could contribute to a more formal definition of a research area in construction and lead to greater effectiveness of construction firms.

The reasons for conducting the study on competitive success stemmed from the view of the 6 sigma and CMMI enthusiasts that there is wastage in managerial effort in the majority of companies approaching 40–50%. The experience of practitioners working to assist companies improve their performance bears this out. These claims are discussed under the topic headings.

The use of these variables or concepts in other industries is based on a larger study of the competitive strategy of the firm, the business environment in which the firm operates and the internal strategies chosen to facilitate achievement of the external competitive strategy (Ireland 2007:1). The other industries on which this currently reported study was based are shown in Table 1.

Issues of whether the product manufacture and the building industry are part of construction are relevant. However, the processes used in construction, of feasibility, planning and design, production, commissioning and hand-over, and possibly operations, are similar to those in a number of other industries such as defence equipment development, shipping design and construction, and often conversion, and production of new products. Even development of software solutions uses similar processes. All companies studied were engaged in a technology environment and under competitive pressure.

The other concepts or variables which are examined have been chosen because they are generally not readily discussed or assessed by construction researchers, which relates to objective 1. These are as follows:

1. CMMI;
2. Enterprise architecture (Cronbach α of 0.7 or greater);
3. Entrepreneurship (Cronbach α of 0.7 or greater);
4. PMBOK versus PRINCE2 (Cronbach α of 0.7 or greater);
5. Portfolio (Cronbach α of 0.7 or greater);
6. Requirements;
7. Vision.

Competitive strategy and business environment are described below because of objective 2.

The concept of competitive strategy of the firm, the business environment and the internal strategies chosen to facilitate achievement of the external competitive strategy has certainly been addressed by many CME papers, even if not quite so formally. The larger study (Ireland 2007: 1), of which these variables form a part, considered the relative effect of many other internal strategies on the achievement of the firm's competitive success, including customer understanding, process management, process reengineering, the use of core competencies, innovation, risk management, leadership, staff development and staff motivation.

The variables have been defined, measured by survey, and those shown above have tested for reliability; they were then shown to correlate with competitive strategy at the 5% level of significance or better.

CONSTRUCTION COMPARED WITH OTHER INDUSTRIES

Many authors have described the construction industry including Ofori (1990), Nam and Tatum (1989) and Hillebrandt (1984). Hillebrandt defines construction as including the organisations involved in the construction process and this process aspect of feasibility, planning and design, implementation and commissioning, has been used as a basis for accepting the validity of comparison with other industries.

Some major industry bodies of knowledge such as the Project Management Body of Knowledge (PMBOK) include construction with defence, IT and manufacturing.

USE OF THE VARIABLES IN OTHER INDUSTRIES

Competitive strategy

Andrews (1991: 44) says corporate strategy is the pattern of decisions in a company that: determines and reveal its objectives, purposes, or goals; produces the principal policies and plans for achieving those goals; defines the range of business the company is to pursue; and the economic and non-economic contribution it intends to make to its shareholders, employees, customers and communities.

Porter (1980: 35) proposed that there are three potentially successful strategic approaches to outperforming other firms in an industry:

- Overall cost leadership;
- Differentiation;
- Focus or cost and differentiation within a niche.

Dikmen and Birgonul (2006), in their review of international construction research, both examine competitive advantage of firms and endorse the role of the business environment. Bassioni *et al.* (2005) support the need for strategic management. Ofori (2003) looked at factors leading to international competitiveness: using Porter’s diamond framework items, the demand conditions and related and supportive industries, the context for firm strategy and rivalry, and even the role of government and culture, are supportive ideas to business environment of this study. Oz (2001) is also supportive.

ISO 9000 is directed at quality and quality is a reasonable basis for competitive strategy.

Stalk and Hout (1990) make a strong case for competing by using time as the competitive weapon. This can take a number of forms such as reducing delivery time of the completed product, reducing response time of enquiries for proposals and reducing response time while operating a project. As all projects require a period of investment, usually without returns during the life of the project, shortening the project duration can significantly increase return on investment.

Hamel and Prahalad (1994: 146) outline the concept of ‘fit’ as being important in successful competion strategy. Fit is a good relationship between strategic intent and the resources available to achieve the strategy. Fit is embedded in the strategic tools of the organisation. Short term fit may be more loose but long term fit needs to be tighter. The concept of strategic tools is related to the concept in this study of internal strategies chosen to achieve the external competitive strategy. Porter (1996) also endorses fit.

The competitive strategies assessed in this study are shown in Table 1.

Business environment

Michael Porter (1980: 4) proposed his famous five forces which drive industry competition, these being Rivalry among existing firms, Threat of new entrants, Bargaining power of suppliers, Bargaining power of buyers and the Threat of substitute products or services.

There are significant differences between the forces which drive various industries. These include: rate of change of technology; the degree of mechanisation versus craft production; the extent to which competition is local versus global; degree of specialisation of key players; and, inherent complexity of tasks.

Mintzberg and Quinn (1991) see technology including scientific discoveries and the impact of related product developments, and the less dramatic process improvements and the progress of automation and data processing.

Political forces are relevant to how well a company survives. The fact that so many corporations make donations to political parties suggests there is value in political connections and power. Advance notice of changes in government priorities are essential to good planning. Key issues are: sensitivity to political issues, political connections; resources committed to political connections. Li *et al.* (2005) support the need for political support.

Businesses are influenced by consumer attitudes and behaviour and this depends on such factors as the age structure of the population and the nature of work. Porter (1980: 238–241) sees industry maturity providing significantly different conditions under which businesses operate. Changes occur to competitive forces, customer experience, the emphasis on costs and service, the marketing and distribution methods required and falling profits, among other effects.

An organisation’s environment can range from stable to dynamic (Mintzberg 1979: 268). Operating a business in rapidly varying business conditions produces very different people and business systems than in a stable environment. It also reduces the ability of a company to use stable and even automated processes.

An organisation’s environment can range from simple to complex. Mintzberg (1979: 262) points out that the more sophisticated the technical system of an organisation, the more elaborate will be the administrative structure, the more professional the workforce and the more liaison devices are required to coordinate the work of the specialists.

Market diversity may result from a broad range of clients to a narrow one. Clearly market diversity affects the structure through a third variable, the diversity of the work to be done (Mintzberg 1979: 269). Thompson *et al.* (2005: 248–279) outline differences between various industries, which are a recognition of the business environments in which the industries are operating. While it may be considered that construction has a reasonably uniform environment, economic cycles in each country, the different stages of development between countries, and other factors ensure that the business environment is a factor in competitive success.

INTERNAL STRATEGIES CHOSEN TO FACILITATE ACHIEVING THE EXTERNAL COMPETITIVE STRATEGY

A number of authors have commented on choices by firms to achieve their external strategy. Porter (1996) speaks of a number of management tools being spawned to achieve competitive success including, total quality management, benchmarking, time-based competition, outsourcing, partnering, reengineering, change management and others. Objective 2 of this paper is to illustrate a more formal comparison of these management tools in order to identify which are more suited to achievement of a firm's particular competitive strategy.

The main approach in Hamel and Prahalad (1994) is based on the notion of firms choosing internal actions in order to achieve external strategic objectives. Kaplan and Norton (1996) also address these internal strategies in proposed a simple approach that firms would achieve financial results if they focused on customers, their internal processes and the learning and growth of their staff. By implication the organisations proposing tools to assist the industry, such as ISO 9000, CMMI, PMBOK (PMI, 2004) and SWEBOK (IEEE 2004), are directly addressing the need for internal processes and competencies in firms to assist their performance.

The following concepts or variables are outlined by discussing how they are used in other industries and then by considering the possible benefits in construction.

CMMI

Capability Maturity Model® - Integration and (CMMI℠) are registered in the US Patent and Trademark office; CMMI is a service mark of Carnegie Mellon University; CMMI℠ was sponsored by the US Department of Defence in order to capitalise on process capability.

A key reason for adopting CMMI in organisations is the contention of Carnegie Mellon that the following savings for organisations operating at CMMI Level 5 can occur (CMMI 2006 associated presentation) with schedule savings of up to 50%, cost reductions of up to 34% and productivity improvement of 61%.

The point is made that process improvement activities compete for corporate resources therefore the most effective need to be chosen. The Defence Materiel Organisation of Australia are encouraging contractors to adopt CMMI in order to improve project consistency (Defence 2003). CMMI is an extension of earlier work by Deming (1986).

CMMI (2006: 3) comments that capability maturity is set in ‘the high velocity environment of the twenty-first century …. in which nearly all organisations have found themselves building increasingly complex products and services’. No single organisation is responsible for all of the product in manufacture, defence, software and IT&T. Therefore all of these stovepipe organisations need to be integrated by a common set of processes. However, this is the world construction has operated in for some time, so the arguments of need should equally apply to construction.

The definition of a CMM allows the community to develop different models supporting different approaches to process improvement CMMI (2006: 6).

CMMI is consistent with other capability maturity models such as Armstrong (2001) and Kerzner (2001) in defining five levels of achievement of processes of Level 1 Initial; Level 2 Managed; Level 3 Defined (and managed with a consistent process across the organisation CMMI (2007:33); Level 4: Quantitatively Managed (a level 3 process, which is controlled using statistical and other quantitative techniques); and Level 5: Optimising (continual improvement of a level 4 process).

There are 22 process areas in CMMI (2006: 18), most of which appear relevant in the construction industry. These include:

1. Causal analysis and Resolution (tracing the cause of defects);
2. Organisational process definition;
3. Project planning;
4. Risk management;
5. Project monitoring and control;
6. Organisational innovation;
7. Supplier agreement management;
8. Validation ;
9. Verification;
10. Organisational training.

Sarshar *et al*. (1999) investigated capability maturity in construction under their SPICE research (Standardised Process Improvement for Construction Enterprises). Their conclusion was that many of the basic process concepts are applicable in construction but problems may occur from supply chain arrangements. Voordijk *et al*. (2003) have briefly discussed a Capability Maturity approach.

The question remains of whether the construction industry in most countries is too unsophisticated for capability maturity. While this may be so for many of the smaller contractors it should not be true for the larger and multi-national contractors. While the aim of CMMI is to integrate CMMs, it could be more appropriate to produce a construction CMM.

Enterprise architecture

Schekkerman (2004) sees enterprise architecture as a complete expression of the enterprise’s masterplan, which acts as a collaborative plan between aspects of business planning such as: goals, visions, strategies, governance principles, aspects of business operations, such as business terms, organisation structures and processes and data, aspects of automation, such as information systems, databases, and the enabling technological infrastructure of the organisation, such as computers.

The Zachman Framework, developed in I987 at IBM, is an early version of Enterprise Architecture as shown in Schekkerman (2004: 133). Schekkerman also outlines a number of organisations which have some form of enterprise architecture, including a number of US Department of Defence architectures (145–182). Purdue University have an architecture for implementing computer aided manufacturing projects (183) and the German Federal Government has standards for implementing e-commerce applications (191).

While all organisations have a set of rules, either explicitly written or implied, to exercise direction and control of its units, the issue is how formally this architecture is stated and the composition of it. Simple examples are planning for future work, the rules for delegation, the capability of computing systems and the quality procedures.

Enterprise architecture does occur in the construction industry although it is not given this name except by a few consultants offering services. Research could be conducted to identify the common elements of a construction enterprise architecture, which should at least include: firm vision and mission, value propositions, target customer information, distribution channels, links with various customers, the value configuration, core competencies, the partner network, cost and schedule data, the revenue model for the company, rules for operating the business, including delegations, firm processes, position descriptions, and salary scales, and lessons learned, among others (Osterwalder *et al. 2005: 18).* The configuration of IT to support these functions is crucial.

Entrepreneurship

Bolton and Thompson (2000) see entrepreneurship in terms of what entrepreneurs do: they are individuals who make a significant difference, they are creative and innovative, they spot and find the resources to exploit opportunities, they are determined in the face of adversity, they manage risk, put the customer first and create capital.

Timmons (2002: 37) sees the entrepreneurial process as a value creation process by a team identifying an opportunity and then providing the resources to develop the opportunity. Uncertainty is involved. The process requires creativity, leadership and communication (2002: 41). The process of creating, shaping and recognising opportunities is assisted by differentiation and foresight, concepts which have been well explored (Peansupap and Walker 2006). Timmons, like a number of other authors, including Bollier (2006), see the internet creating more democratic opportunities.

Dollinger (1995: 78) sees entrepreneurs reacting to political, economic, industry, environmental, ecological, sociological and technological issues.

Obvious examples of entrepreneurship in construction industry are identification of new business directions, product development and property development, especially the use of different styles, building forms, residential densities.

Operational excellence and sustained competitive advantage

The concept of operational excellence versus sustained competitive advantage was initiated by Porter (1996). His contention was that operational excellence is not adequate for a company to pursue. In fact Porter's view is that pursuit of operational excellence is not even strategy.

Osterwalder *et al.* (2005: 18) suggest aspects of sustained competitive advantage include value propositions, target customer information, distribution channels, links with various customers, the value configuration, core competencies, the partner network, and the revenue model for the company. More detailed examination of value propositions, value configuration, core competencies and other bases for sustained competitive advantage would be of significant value in construction.

PMBOK versus PRINCE2

The Project Management Institute (USA based although there are offices in many cities worldwide) now has over 250,000 members and over 700 Registered Education Providers, suggesting a strong following. PRINCE2 was developed in the UK. Both are models used to manage projects, although the models are quite different is their structure. PMBOK (PMI 2004) and PRINCE2 (Bentley 2002) are the two most popular models of project management.

PRINCE2 is a layered approach of looking at a number of processes at the top level, then drilling down to a second and then a third level. The PRINCE2 processes are: directing a project, start-up, initiating a project, controlling a stage, managing stage boundaries, closing a project, managing product delivery and planning. This is within a broad context.

The PMBOK model is easy to understand based on three key variables of project phase, nine knowledge areas and five processes. The knowledge areas are: integration, scope, time, cost, quality, risk, human resources, communication and procurement. The processes are initiating, planning, control, executing and closing (PMI 2004).

Given the success of both models and the fact they are quite different, a comparison of each and in which circumstances either is more applicable, could be of value.

Portfolio

Schekkerman (2004) sees enterprise portfolio management falling directly below Mission, Vision and Strategy, in that order. Portfolio management is responsible for determining investment strategy, asset management, risk management and environment management; these sit above enterprise architecture; this is a form of enterprise investment management.

Some of the key activities that are essential to portfolio management are: translating organisational strategies into specific initiatives or business cases that become the foundation for programs and projects; identifying common systems to assist the projects in the portfolio, identifying and initiating programs and projects; providing, allocating and re-allocating resources to programs, projects and other activities; maintaining a balanced project portfolio; and, supporting the organisational project management environment.

Portfolio management promotes understanding of the interrelationship between organisational processes and the successful completion of programs and project processes. Blismas *et al.* (2004) recognise programs and portfolios and found value in optimising them.

Further research work could explore the more important aspects for relating project results to firm goals, other than financial.

Requirements

A requirement is a condition or capability that must be met or possessed by a system, product, service, result or component, to satisfy a contract, standard, specification or other formally imposed documents. Requirements include quantified and documented needs, wants and expectations of the sponsor, customer and other stakeholders, which are testable (PMI 2004).

SWEBOK comments: ‘Software requirements express the needs and constraints placed on a software product that contribute to the solution of some real-world problem’ (IEEE 2002: 2.1).

A requirement is the identification of a need, want or desire, which an installed system must satisfy. Key issues to consider are: ‘what is the system to accomplish in terms of operations and functional performance: when is the system needed, what are the consumer requirements, what is the expected operational life of a system; what effectiveness requirements should the system exhibit, and how is the system to be supported in terms of its life cycle (Blanchard & Fabrycky 1990: 35).

In software terms functional requirements describe the functions that the software is to execute; for example formatting some text’ non-functional requirements act to constrain the solution’ (IEEE 2004: 2.2).

A key issue is if a specification directly prescribes a solution (eg 220mm brick wall), it limits the supplier’s scope to innovate. By comparison, the specification of requirements, which do not specifically describe the solution, but describe the functions of the solution, lead to greater innovation, even if it is more difficult to use such descriptions. Use of requirements is more applicable in state of the art work such as defence equipment and IT. However, construction projects in which needs were expressed more in purely capabilities of the solution terms, should produce more innovation.

Shen *et al* (2005) examine requirements in construction, which are supportive of the view of this study.

Categorisation of standard requirements applicable to construction, development of standard tests for these, and a traceability system similar to defence, could be a worthwhile research area.

Ireland

SUPORT FROM ANOTHER STUDY

Ireland (2007: 1) conducted a broader research study which investigates the relationship between the three groups of variables which have been outlined however this broader study also included a number of other internal strategies in order to determine the relative merit of each.

The research was conducted on a group of firms operating in a technology environment. The relationships between the three variables shown in Figure 1 were investigated.

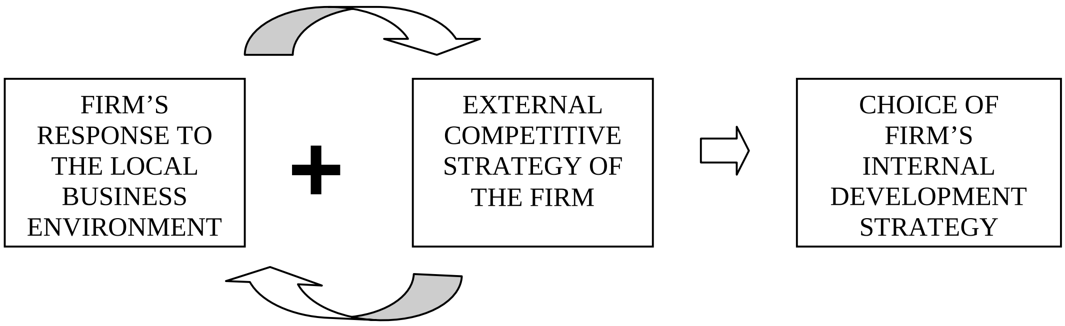


Figure 1: Firm's response to the local business environment leading to an external competitive strategy, which then leads to choice of the internal development strategies of the firm chosen to support the chosen external strategies

Hypotheses
This broader study had the following hypotheses:

1. Choice of a firm's external competitive strategy recognises the local business environment (as illustrated in Table 2);
2. Achievement of a firm's external competitive strategy in enhanced by encouragement of internal firm development strategies (as illustrated in Table 2);
3. The local business environment influences choice of internal firm development strategies (as illustrated in Table 2).

De Haan *et al.* (2002) considers internal and external conditions and fit as a related concept. De Haan is generally supportive.

Sample
Forty eight organisations took part in the survey from over 100 offered.

The firms were in the following roles:

Table 1: Firm types in the sample

Firm Type	Number
Air system control	2
Architectural design	1
Construction	3
Defence	10

Film	1
Finance	1
Health	1
Human resources (the technology to support the business)	2
Logistics	1
Manufacturing	12
Non-construction technology consulting	7
Oil well manufacture	2
Rail	2
Real estate	1
Technology entrepreneurship	1
Wholesale trade (the technology to support the business)	1

Only the variables relevant to this paper are reported.

Research method

Components of competitive strategy were not subjected to principal components analysis as competitive strategies need to be clearly different.

Elements of business environment were treated by principal components analysis and three components emerged, these being:

Environment 1 = (0.870Rivalry determinants, + 0.740Price sensitivity + 0.646Threatsubstitutes + 0.595Entry barriers);

Environment 2 = (0.859Politicalissues + 0.783Socialissues);

Environment 3 = (0.853Execbargaining + 0.853Industrels).

External strategies and some aspects of the internal strategies shown in Table 2 were surveyed by a single measure. Items 3.1 to 3.6 of the internal strategies were analysed by principal components analysis and all had Chronbach α of over 0.7. The others had a single measure. The correlations are shown in Table 3.

Table 2: Proposed relationships examined between external competitive strategy, business environment and the internal strategies chosen to support the external strategies

External Strategy	Business Environment	Internal Strategies used to Achieve External Strategies
1. Minimal cost;	2.1 Technology;	3.1 Vision
2. Minimal cost within a niche;	2.2 Industry;	3.2 Entrepreneurship
3. Adequate quality;	2.3 Economic conditions;	3.3 PMBOK
4. Innovation;	2.4 Ecology;	3.4 PRINCE2
5. Responsiveness;	2.5 Politics;	3.5 Portfolios
6. Time of delivery;	2.6 Social and cultural;	3.6 Enterprise architecture

Ireland

7. Customer value; 8. Market share; 9. Segmenting the market; 10. Fit.	2.7 Demographic; 2.8 Industry profitability; 2.9 Industry growth; 2.10 Industrial relations climate; 2.11 Executive bargaining; 2.12 Complexity; 2.13 Hostility; 2.14 Diversity; 2.15 Stability.	Further parameters were extracted from the above: 3.7 CMMI; 3.8 Requirements; 3.9 Operational excellence versus sustained competitive advantage.

It is probably not surprising to find that minimum cost within a niche and minimum delivery time were indicated as the most important competitive strategies with this small sample.

Table 3: Correlations between the external strategy chosen and the measures of the internal strategy of the firm: note ♦ indicates correlations of 5% significance or better.

External Competitive strategies from Table 2 ⇒	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Internal Strategies to achieve external competitive strategy ⇓										
CMMI		♦								
Enterprise architecture		♦				♦				
Entrepreneurship		♦				♦				
Operational Excellence rather than sustained competitive advantage										♦
PMBOK						♦				
Portfolio		♦				♦				♦
PRINCE2										♦
Requirements		♦								♦
Vision		♦				♦			♦	♦

Table 4: Correlations of business environment and external strategies.

External competitive strategy	**Business environment units correlated at 5% level of significance or better**
Minimal cost within a niche	Supplier power Buyer power
Segment the market	Industrial relations Environmental complexity Hostility
Fit	Ecological issues Demographic changes

Furthermore, based on the relationships shown in Figure 1 and illustrated in Table 2, correlations at the 5% level of significance or better are shown in Table 5.

Correlations between External strategy and Business environment
Recognising that firms concentrate on external strategies of minimal cost within a niche and segmenting the market, the correlations with business environment and these external strategies revealed the following correlations:

CONCLUSIONS

The research has shown that there are a number of concepts or variables which construction researchers could investigate more thoroughly, which are relevant in other areas of technology business and management. The research has also indicated that a more formal approach to considering three classes of variables, the competitive strategy of the firm, the business environment in which the firm operates and the internal strategies chosen to facilitate achievement of the external competitive strategy, appears worthwhile to be investigated in a larger sample.

Table 5 correlations between measures of business environment and measures of internal strategy of the firm at 5% level of significance

Correlations between measures of business environment and measures of internal strategy of the firm at 5% level of significance		
Env 1	**Env 2:**	**Env 3**
Nil	Vision* PMBOK** Enterprise Architecture*	Enterprise Architecture*

All of the variables investigated, these being CMMI, Enterprise architecture, Entrepreneurship, Operational Excellence rather than sustained competitive advantage, PMBOK, PRINCE2, Portfolio, Requirements and Vision were shown to support particular competitive strategies. Minimising cost within a niche and minimising time of delivery, segmenting the market and fit, were shown to be key competitive strategies.

REFERENCES

Andrews, K (1991) The concepts of corporate strategy strategy,. *In:* H Mintzberg and J B Quinn, *The strategy process*. Englewood Cliffs: Prentice Hall.

Armstrong, S (2001) *Engineering and product development management.* Cambridge: Cambridge University Press.

Bassioni, H A, Price, A D F and Hassan, T M (2005) Building a conceptual framework for measuring business performance in construction: an empirical evaluation, *Construction Management and Economics*, **23**, 500.

Bentley, C (2002) *PRINCE2, a practical handbook.* Oxford: Butterworth Heinemann.

Blanchard, B and Fabrycky,W (1990) *Systems engineering and analysis*. Englewood Cliffs: Prentice Hall.

Blismas, S, Sher, W, Thorpe, A and Baldwin, A (2004) A typology for clients' multi-project environments, *Construction Management and Economics,* **22,** 357–371.

Bollier, D (2006) *When push comes to pull.* Denver: The Aspen Institute.

CMMI (2006) *CMMI for Development, Version 1.2*, Carnegie Mellon Software Engineering Institute, CMU/SEI-2006-TR-008.

Defence (2003) Defence Annual Report, 2002–2003.
De Haan, J, Boordik, H. and Joosten, G -J, (2002) Market strategies and core capabilities in the building industry, *Construction Management and Economics*, **20**, 109–118.
Deming, W (1986) *Out of the crisis*. Cambridge: MIT.
Dikmen, I and Birgonul, T (2006) A review of international construction research: Ranko Bon’s contribution, *Construction Management and Economics*, **24**, 725–733.
Dollinger, M (1995) *Entrepreneurship strategies and resou*rces. Boston: Irwin.
Hamel, G and Prahalad, C K (1994) *Competing for the future*. Boston: Harvard Business School Press.
Hillebrandt, PM (1984) *Economic theory of the construction industry*, 2ed. London: Macmillan.
IEEE (2004) Software engineering body of knowledge (SWEBOK), IEEE Computer Society, http://computer.org.
Ireland, V (2007.1) Competitive strategy of the firm, the business environment and internal strategy support – a pilot study – as yet unpublished.
Kaplan, R and Norton, D (1996) *The balanced scorecard.* Boston: Harvard Business School Press.
Kerzner, H (2001) *Project management using a project management maturity model.* New York: Wiley.
Li, B, Akintoye, A, Edwards, P J and Hardcastle, C (2005) Critical success factors for PPP/FPI projects in the UK construction industry, *Construction Management and Economics*, **23**, 467.
Nam, C H and and Tatum, C B (1988) Major characteristics of constructed products and resulting limitations of construction technology, *Construction Management and Economics*, 6, 133-148.
Ofori, G (1990) *The construction industry – aspects of its economics and management*. Singapore: Singapore University Press.
Ofori, G (2003) Frameworks for analysing international construction, *Construction Management and Economics*, **21**, 379–391.
Osterwalder, A, Pigneur, Y, Tucci, C L (2005) Clarifying business models: origins, present, and future of the concept, *Communications of the Association for Information Systems*, Volume 15, May, 1–40.
Oz, O (2001) Sources of competitive advantage of Turkish construction companies in international markets, *Construction Management and Economics*, **19**, 135–144.
Peansupap, V and Walker, D (2006) Innovation diffusion at the implementation stage of a construction project: a case study of information communication technology, *Construction*, **24**, 321–332.
Porter, M (1980) *Competitive strategy.* New York: Collier Macmillan.
Porter, M (1996) What is strategy, *Harvard Business Review*, Nov–Dec, 61–78.
PMI (2000) A *Guide to the project management body of knowledge*, 2ed. Pennsylvania: Project Management Institute.
PMI (2004) A *Guide to the project management body of knowledge*, 3ed. Pennsylvania: Project Management Institute.
Sarshar, M, Finnemore, M, Haigh, R and Goulding, J (1999) Construction Informatics Digital Library, w78-1999-2838.content.
Schekkerman, J, (2004) *How to survive in the jungle of enterprise architecture frameworks: creating or choosing an enterprise architecture framework.* Victoria: Trafford Publishing.

Shen, Q, Li, H, Chung, J and Hui, P -Y (2004) A framework for identification and representation of client requirements in the briefing process, *Construction Management and Economics*, **22**, 213–221.

Stalk, G and Hout, T (1990) *Competing against time*. New York: The Free Press.

Thompson, A A and Strickland, A J (2005) *Strategic management*. Boston: McGraw-Hill Irwin.

Thompson, A A, Strickland, A J and Gamble, J E (2007) *Crafting and executing strategy*. Boston: McGraw-Hill Irwin.

Timmons, J A (2002) *New venture creation*. Boston: Irwin McGraw-Hill

Voordijk, H, Van Leuven, A and Laan, A. (2003) Enterprise resource planning in large construction firm: implementation analysis, *Construction Management and Economics*, **21**, 511–521.

MANAGEMENT FUNCTIONS AND COMPETITIVENESS IN THE PORTUGUESE CONSTRUCTION INDUSTRY

Brígida Pires[1], José Cardoso Teixeira[1] and Hélder Moura[2]

[1]*Department of Civil Engineering, University of Minho, Campus de Azurém, Guimarães, 4800-058, Portugal*
[2]*Estradas de Portugal, EPE, Almada, Portugal*

The construction industry faces a wide range of challenges that ought to be addressed if it is to maintain and, if possible, improve its competitiveness. The key interrelated elements of competitiveness have been the focus of many international research projects and studies. The measurement of this success and the quality of the project's performance depends on the achievement of the main construction management function objectives, namely time, cost, quality and safety, which are the focal indicators for a healthy and a competitive construction sector. However, frequent delays, cost overruns, insufficient quality and lack of safety are symptoms of the lack of competitiveness recognized in most construction projects concluded in the last years in Portugal. As a result, a research project has been launched to better understand and clarify the reasons behind the lack of achievements of these management functions that affect the competitiveness of the Portuguese construction industry. Results of the survey obtained so far indicate that the main causes for the lack of achievement of the construction functions are due to design and client responsibilities, inadequate construction management and lack of specific training.

Keywords: cost overruns, delays, quality, health & safety, Portugal.

INTRODUCTION

The approach to assess competitiveness is multi-faceted. It can be evaluated at different levels – national, firm or economic activity — as well as domestically, regionally and internationally. At each level, there are different indicators for competitiveness. For a nation, competitiveness is the capacity to achieve sustained economic growth and employment while remaining open to international trade. For a firm, being competitive involves increasing market shares over competitors, through either more competitive pricing or quality improvement of products (Reinaud 2005). Measuring competitiveness is a key issue in any economic activity and construction is not an exception.

Different frameworks have been suggested to measure competitiveness for countries, economic activities and single firms. Obviously, the ways this may be achieved is highly dependent on the purpose and aim of the study but the so-called Porter's diamond seems to be in widespread use. The diamond (Porter 1990) has been used to explain each country's industrial trends, depending on four major determinants (factor conditions, market conditions, industrial environment and corporate strategy) and two external factors (government and chance).

[1] brigidapires@civil.uminho.pt

Recent critical reviews suggest new factors and a different organization of Porter’s Diamond to better suit the construction industry (Ofori 2003), for instance the Hexagon framework proposed by Flanagan *et al*. (2005). This report considers that the industry is competitive if it satisfies the national needs of the four main stakeholders: shareholders, clients, employees and the overall society. To achieve these goals, it must be profitable, predictable in time and cost, innovative, achieves harmonious relationships, achieves competitive wages, has a safe and healthy work environment, behaves ethically and complies with environment and sustainable regulations.

However, to be effective these goals should be measured in order to evaluate the industry’s performance. The most common approach to measure the performance of a project is with the use of key performance indicators if comparable data on similar projects is available. An alternative quantitative approach is to measure the three fundamental indicators at project level: time, cost and quality, commonly known as the iron triangle (Atkinson 1999). More recently, the consolidate framework for measuring project success also includes health and safety (Chan and Chan 2004).

The lack of fulfilment of cost and time management functions often leads to project overruns producing immediate effects on construction stakeholders and on the country’s economy and competitiveness. National construction projects that have experienced extreme cost overruns and delays include a performance hall in Porto (Casa da Música, 2005), a bridge in Coimbra (Ponte Europa, 2004), an urban tunnel in Lisbon (Túnel Rodoviário do Marquês, 2007) and an underground railway tunnel in Lisbon (Metro do Terreiro do Paço, 2007).

Cost and time overruns have been thoroughly studied internationally but unfortunately, at national level, research results on these overruns continue to be very rare. Only recently did the Board of Engineers submit to the National Court of Audit a proposal with recommendations for the reduction of cost and time overruns in public works construction projects (OE 2006). Simultaneously, the Board of Architects also decided to take affirmative action by undertaking a project with the National Court of Audit regarding the identification of situations that originate cost overruns in public works construction projects (OA 2006).

Another issue reportedly pointed out in the media is the lack of safety in the Portuguese construction sector that continues to lead the number of work-related accidents and fatalities. Although responsibilities of all who intervene in the construction process have been reinforced by recent law amendments on risk prevention at work, numerous violations continue to occur with dramatic consequences. Costs related to work accidents as well as health problems related to this profession affect not only injured workers but also the employer, insurance companies and society in general.

According to the General Labour Inspection, 157 fatalities occurred in all the economic activities in Portugal during 2006. The construction industry was accountable for 71 (or 45%) of those fatalities (IGT 2007). But more important than statistical data on labour fatalities is the analysis of available information on the causes for these unfortunate events and find solutions for their mitigation. In 2005, the incidence rate of work-related fatalities in the Portuguese construction was 30.5 per 100,000 workers.

A further aspect regarding the need for better quality in the Portuguese construction sector has impelled proposals for the revision of legislation, namely increasing the guarantee period of buildings. Shorter life cycles of construction materials and components cause unexpected expenses that new end-users have to endure. However, to help mitigate these intolerable costs leaving end-users more satisfied, it is necessary to improve the quality of construction materials and its components.

In brief, cost and time overruns, the lack of safety during the construction phase and insufficient quality of the final built facilities have diverted the industry from fully advancing towards a more competitive ground in this country. A number of explanations have pointed out for these situations: the specifics of the industry, the production structure, the phased development of projects, the lack of adequate labour training, the weather conditions, etc. However, these do not explain why it evidences the above symptoms in national territory while it seems to be more competitive in the international market.

Therefore, in order to better understand and clarify the reasons behind the lack of achievements of the main management construction functions, a research project was launched, entitled “Reasons for lack of accomplishment of schedule, costs and safety objectives in construction”, financed by the Science and Technology Foundation (FCT). Comprehending the causes and formulating methods to better manage and control these issues is essential for improving the competitiveness of the Portuguese construction industry, influencing the credibility of professionals and the country’s image in this sector.

Results from the project will be used to recommend measures to increase competitiveness of the Portuguese construction industry. Work accomplished so far over the last two years is presented in this paper.

RESEARCH METHODOLOGY

The inquiry

Prior to the creation of the inquiry, specific boundaries were set to define the cluster of information that would be gathered from the industry and compiled in a database for subsequent treatment. Consequently, only information regarding construction projects launched between 1998 and 2004 and with an initial contract value over €10,000,000 was gathered.

Gathering information on public projects was unproblematic due to the available information on the procurement phase of these projects in Official Journals. Information on approximately 500 public projects had been collected. However, efforts to gather information on private projects were abandoned due to the scarcity of available data.

Opinions were collected from relevant client and contractors involved in the projects previously assessed through an internet-based questionnaire available on the project’s website. This was created with the intent of disseminating the project and its objectives and encouraging respondents to take part in it.

Clients and contractors involved in the projects assessed were contacted by email and fax. These included information on the ongoing project, link to the project’s website, questionnaire and its direct internet link and also an individual database that contained only the projects that respondent had been involved in the specified time period.

The questionnaire focused on the characteristics of each project and evidence of the lack of achievement of cost, time, safety and quality management functions. The first part of the questionnaire aimed at gathering specific information on the project under assessment (project description, client and contractor(s) identification, initial contract value, type of contract, starting date and initial project duration).

Subsequently, respondents were asked to quantify the lack of fulfilment of each management function. Consequently, information was requested on the final cost and duration, number of accidents (fatal and non-fatal), number of workers, number of work-hours, days lost and the number of quality non-compliances and claims).

For each project, respondents were asked to point out and graduate in a scale of 1 (less important) to 4 (most important) the possible causes for the lack of fulfilment of each management variable:

- Main causes for delays: materials, equipment, workforce, contractor management, client responsibility, design, project managers, financial problems, contract, institutional relations, project specifics, external factors.
- Main causes for cost overruns: design errors and omissions, site conditions, client responsibility, cardinal changes imposed by third parties, external factors.
- Main causes for lack of safety: lack of individual protection, lack of collective protection, lack of specific training, high risk activity, lack of equipment maintenance, insufficient and inadequate task preparation, direct orders from client/client representative, inadequacy of selected materials and/or equipments, force majeure.
- Main causes for poor quality: inadequate design solutions, poor work execution or construction errors, inaction or errors in clients decisions and performance of project managers, inaction or errors in clients decisions and performance, inadequate materials, products or construction processes, inadequate or poor inspection to site conditions, external factors

Respondents were given also the opportunity to indicate other causes not mentioned in the questionnaire and possible actions for mitigating these.

Reply from the industry

Although approximately 500 projects had been previously identified, only 66 answers were received after a six-month period of inquiry. Additionally, two global responses representing 53 projects were also received. Therefore, analysis will only be based on the 64 individual answers. Table 1 illustrates the distribution of answers by types of projects ands respondents.

Table 1: Distribution of projects by type of construction

Type of projects	Distribution of answers (%)	Clients	Contractors
Civil works (buildings, urban development)	19%	58%	42%
Infrastructure (water, gas, sewer)	17%	64%	36%
Industrial	8%	60%	40%
Dam/maritime	16%	70%	30%
Roads/highway/railway	36%	48%	52%
Environment	5%	33%	67%

Responses were only obtained after several diligences. Persisting phone calls, emails, faxes, letters to the board of directors and personal contacts with key personnel of contractors and clients were strategies adopted by the research team. A large number of the companies inquired had no available data readily available to provide. In other cases, although data was available, it had not been adequately treated. This lack of relevant records on past projects has been identified as the first reason for the lack of competitiveness of Portuguese construction industry (Moura and Teixeira 2006).

The conservative behaviour of the industry, key personnel involved in the projects no longer with the company, fears that data would be misused against respondents, and that records were too hard to retrieve or missing were just a few aspects that led to the lack of response from the industry.

ANALYSIS OF RESULTS

Information gathered from the industry was quantified by measuring the frequency and the intensity of the causes pointed out by the clients and contractors. In order to measure the importance and the intensity of these causes, an index (*I*) is used given by the expression $I = \sum_{i=1}^{4} x_i a_i$ where a_i is the constant that expresses the weight given to I (ranges from 1 = less important to 4 = most important) and x_i is the frequency of the answers.

The following results emerged from this analysis.

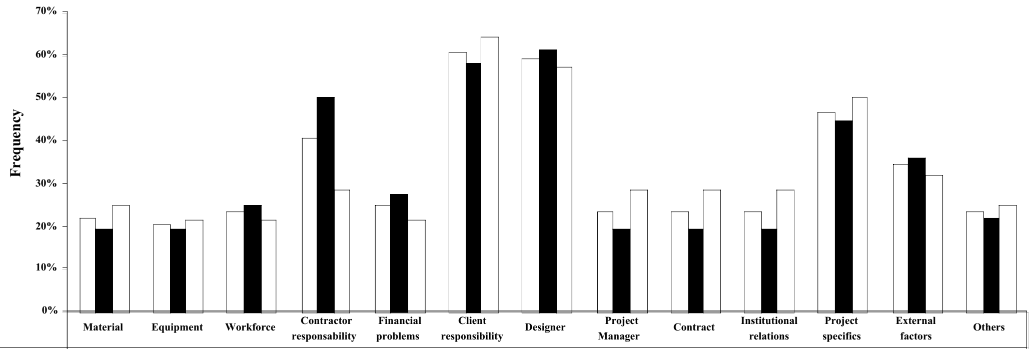
Time function

The quantitative measure for the time function was the delay in each project, expressed in calendar days, in relation to the initial duration. The average initial contract duration was 512 calendar days and the actual duration was 713 days. Therefore, the average delay was 201 days approximately 40% above the expected duration period.

Aggregate answers point out client (61%) and designer responsibility (59%) as the most frequent delay causes, followed by project specifics, contractor responsibility and external factors, with 47%, 41% and 34% of responses.

Compared to the overall results, the clients surveyed firstly point out designer responsibility (61%) and only afterwards client responsibility (58%) as the most frequent delay causes. Contractor responsibility was ranked third with 50% of responses and project specifics ranked forth with 44% of the responses.

As for the contractors' response, the most frequent delay causes ranked similarly as the overall results. Contractors mostly blame the clients (64%), designer responsibilities (57%) and project specifics (50%) as the most frequent delay causes. Contractors blame themselves with only 29% of responses, taking up fifth place. The frequencies of these causes are represented in Figure 1.



	Material	Equipment	Workforce	Contractor responsability	Financial problems	Client responsibility	Designer	Project Manager	Contract	Institutional relations	Project specifics	External factors	Others
□ Total response	22%	20%	23%	41%	25%	61%	59%	23%	23%	23%	47%	34%	23%
■ Client response	19%	19%	25%	50%	28%	58%	61%	19%	19%	19%	44%	36%	22%
□ Contractor response	25%	21%	21%	29%	21%	64%	57%	29%	29%	29%	50%	32%	25%

Main causes for delays

Figure 1: Frequency of delay causes

According to Figure 2, the intensity of delay causes ranks similarly to the frequency causes pointed out by participants for the lack of achievement of project's time management function.

Aggregate answers show that client and designer responsibility reach 116 and 104 points, respectively, followed by project specifics with 71 points (third place) and contractor responsibility with 66 points (forth place).

Contrary to the most frequent cause for delays, previously identified by the clients (designer responsibility), client responsibility has been ranked the most intense cause and designer responsibility second. In the clients' perspective, although designer responsibility contribute more frequently to delays, its **intensity** on the lack of achievement of the project's time function **is not as significant** as the client's responsibility. This is an interesting detail because clients are actually aware that they contribute significantly to the delays and thus low performance of the project.

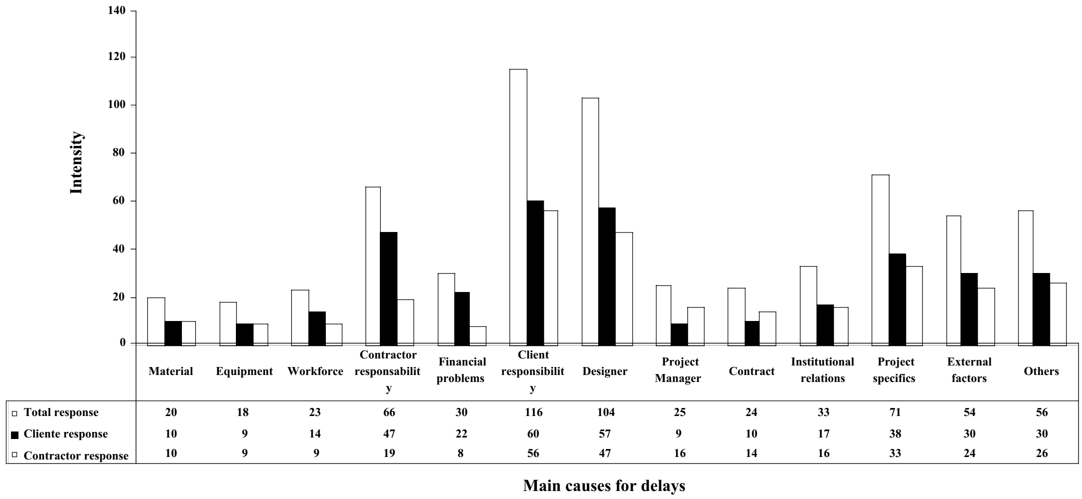
Compared to the overall response, clients point out contractor responsibility as the third most intense reason for delays (47 points) and only after projects specifics as the forth reason (38 points).

Contractors rank the same causes for delays as the overall response: client responsibility (56 points), designer responsibility (47 points); project specifics (33 points). Results distinguish slightly from the overall response since their responsibility only ranks sixth with 19 points. Figure 2 illustrates the intensity of the main causes for delays.

Cost function

Analysis of the cost function was done by comparing the final cost of the project with the initial contract value. The average initial cost of the 64 construction projects surveyed was €16.183.327 while the average final cost reached €18.384.341. As a result, the average cost overrun was € 2.201.014 or 14% of the initial average cost.

Traditionally cost overruns in public projects normally reach the maximum permitted by law: 50% for projects launched up to 1999 and 25% afterwards. However, some caution must be taken when analysing these results, as the reasons behind this low rate of cost overruns can be due to scope changes especially on those projects experiencing final cost reduction.

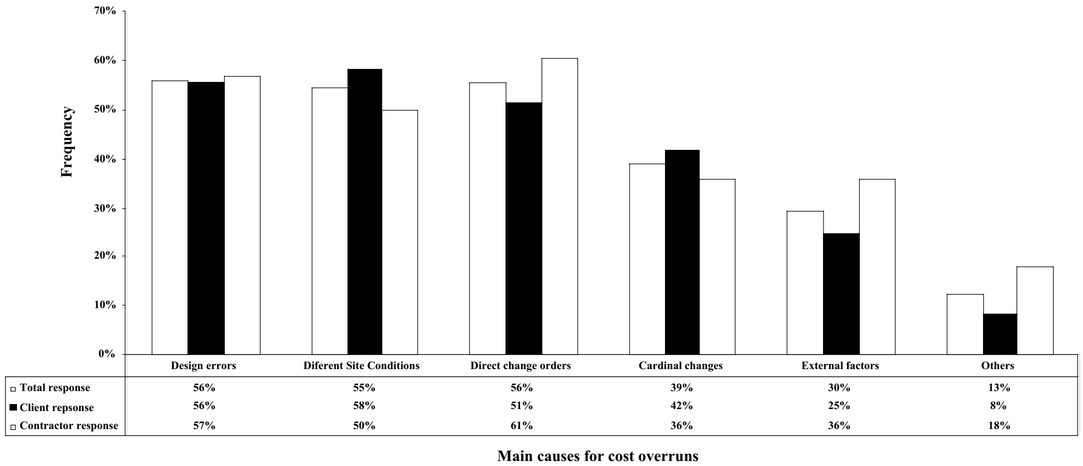


	Material	Equipment	Workforce	Contractor responsability	Financial problems	Client responsibility	Designer	Project Manager	Contract	Institutional relations	Project specifics	External factors	Others
□ Total response	20	18	23	66	30	116	104	25	24	33	71	54	56
■ Cliente response	10	9	14	47	22	60	57	9	10	17	38	30	30
□ Contractor response	10	9	9	19	8	56	47	16	14	16	33	24	26

Figure 2: Intensity of delay causes

The aggregated answers from respondents revealed that design errors (56%), direct changes ordered by clients (56%) and different site conditions (55%) are the most frequent causes for cost overruns in construction projects.

Moreover, the clients' point of view and the contractors' point of view on this issue barely diverge (see Figure 3). Design errors have been ranked by both groups as the second most frequent cause for cost overruns in the projects surveyed with 56% and 57% of responses. While clients rank site conditions (58%) as the most frequent cause for cost overruns, contractors rank direct change orders from clients (61%) as the most frequent cause. On the other hand, whereas direct change orders (51%) ranks third for clients, site conditions fill the spot with 50% of responses from contractors.



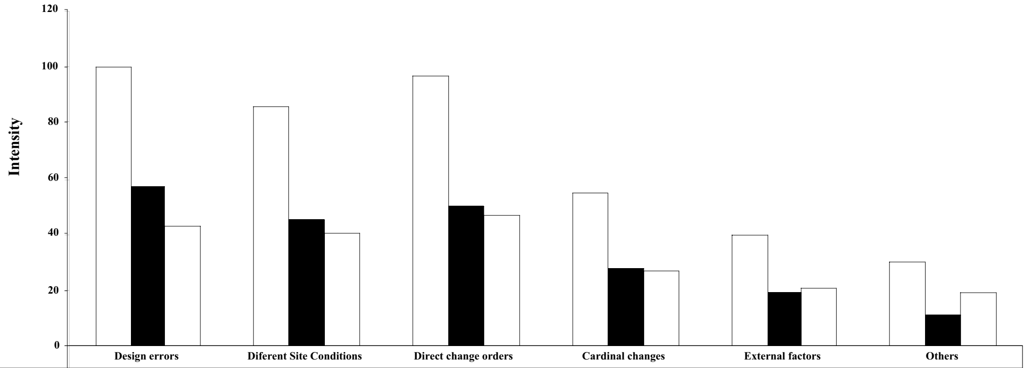
	Design errors	Diferent Site Conditions	Direct change orders	Cardinal changes	External factors	Others
□ Total response	56%	55%	56%	39%	30%	13%
■ Client repsonse	56%	58%	51%	42%	25%	8%
□ Contractor response	57%	50%	61%	36%	36%	18%

Figure 3: Frequency of cost overrun causes

According to Figure 4, the intensity of these causes rank similarly when compared to the frequency causes previously pointed out. Aggregate responses portray design errors (100 points), direct change orders (97 points) and site conditions (86 points) as the most intense causes for the lack of achievement of the project's cost management function.

Clients rank the same causes as the overall response while contractors position direct change orders instead of design errors as the most intense cause.

On the other hand, different site conditions, previously ranked first by clients as the most frequent cause, ranks third as the most intense cause. In the clients' perspective, although site conditions contribute more frequently to cost overruns, its **intensity** on the lack of achievement of the project's cost management function **is not as significant** when compared to design errors and direct change orders.



	Design errors	Diferent Site Conditions	Direct change orders	Cardinal changes	External factors	Others
□ Total response	100	86	97	55	40	30
■ Client response	57	45	50	28	19	11
□ Contractor response	43	41	47	27	21	19

Main causes for cost overruns

Figure 4: Intensity of cost overrun causes

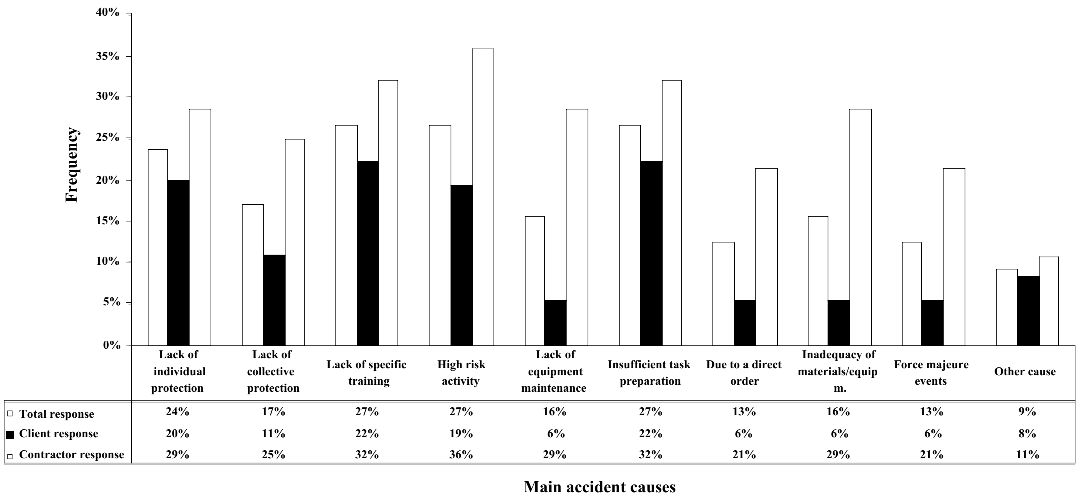
Safety function

The number of fatal and non-fatal accidents, number of workers involved in the projects, number of work hours and the total working days lost due to accidents occurred was the data surveyed for the safety management function. However, the most reliable data is in fact the labour accidents that are reported to the authorities: 3 fatal and 159 non-fatal accidents occurred in the 66 projects surveyed.

According to the aggregate answers, the most frequent reasons for the occurrence of labour accidents are the lack of specific training, insufficient task preparation, high-risk activities and lack of individual protection.

Separate analysis of clients' and contractors' responses showed an equal understanding on the causes for the lack of safety in construction, although more severely classified by contractors. Contractors insist on the high risk of the activities (36%), an issue that normally is beyond their control, while clients attribute a higher degree of severity to contractors as they indicate insufficient task preparation (22%) and lack of specific training (22%). Contractors also hold themselves liable having reported the lack of specific training and insufficient task preparation with 32% of responses. The lack of individual protection and inadequacy/lack of material/equipment are other causes summoned by contractors.

The frequency of the main causes for the lack of achievement of the safety function is represented in Figure 5.

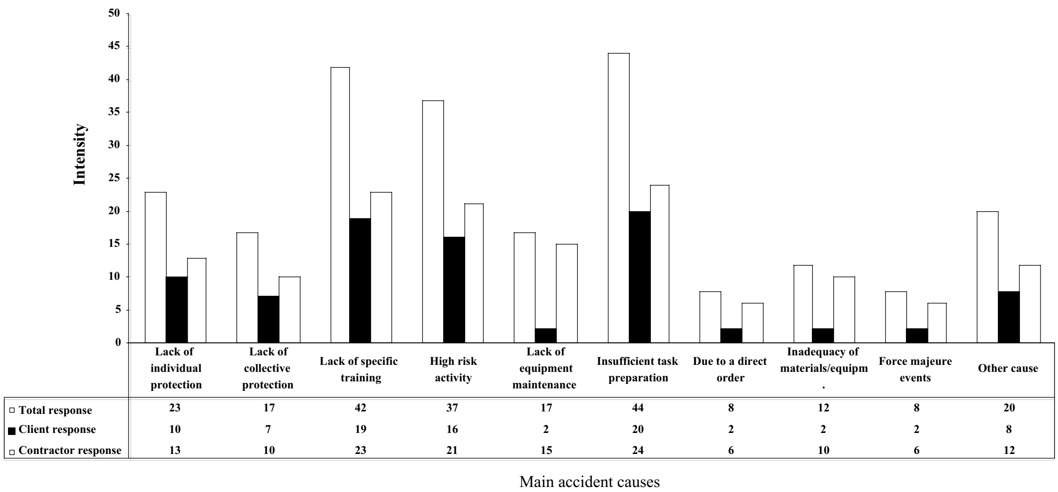


	Lack of individual protection	Lack of collective protection	Lack of specific training	High risk activity	Lack of equipment maintenance	Insufficient task preparation	Due to a direct order	Inadequacy of materials/equipm.	Force majeure events	Other cause
Total response	24%	17%	27%	27%	16%	27%	13%	16%	13%	9%
Client response	20%	11%	22%	19%	6%	22%	6%	6%	6%	8%
Contractor response	29%	25%	32%	36%	29%	32%	21%	29%	21%	11%

Figure 5: Frequency of accident causes

The intensity of these causes rank similarly when compared to the frequency causes previously specified. However, contractors rank insufficient task preparation as the most intense cause whereas it was ranked second as the most frequent cause. In their opinion, although the high-risk activity contributes more frequently to the lack of safety, its **intensity** on the lack of achievement of the project's safety management function **is not as significant** when compared to insufficient task preparation and lack of specific training. Thus, this only comes to show that contractors acknowledge their own fault in contributing to the lack of safety in construction.

The intensity of the main causes for the lack of achievement of the safety function is represented in Figure 6.



	Lack of individual protection	Lack of collective protection	Lack of specific training	High risk activity	Lack of equipment maintenance	Insufficient task preparation	Due to a direct order	Inadequacy of materials/equipm.	Force majeure events	Other cause
Total response	23	17	42	37	17	44	8	12	8	20
Client response	10	7	19	16	2	20	2	2	2	8
Contractor response	13	10	23	21	15	24	6	10	6	12

Figure 6: Intensity of accident causes

QUALITY FUNCTION

The number of non-compliances presented during the construction and operation period of the constructed facility was used to analyse the project's quality function. Table 2 illustrates an abnormal frequency distribution of non-compliances that vary from zero non-compliances in 27% of the projects to more than 1000 non-compliances in 3% of the projects, whereas 44% had no available data.

This abnormal frequency distribution must be handled with some care as it might not explain the real situation of the Portuguese construction projects. Instead, it might explain the consequences and the inexperience in dealing with the recent implementation of Quality Management Systems, which is not compulsory for construction companies in Portugal.

Table 2: Weight of non-compliances

Number of non-compliances	Distribution of answers (%)
0	27%
1	6%
2	5%
3	6%
4–10	5%
100–1000	5%
>1000	3%
No answer	44%

Poor work execution (31%) and inadequate design solutions (27%) are the most frequent causes of poor quality of Portuguese construction projects. The same causes identified in the aggregated answers have also been pointed out in the separate answers given the by clients' and by contractors'. Contractors acknowledge their own low performance identifying poor work execution with 39% of responses and inadequate design solutions with 32% of responses while clients consider these causes to be less frequent (see Figure 7).

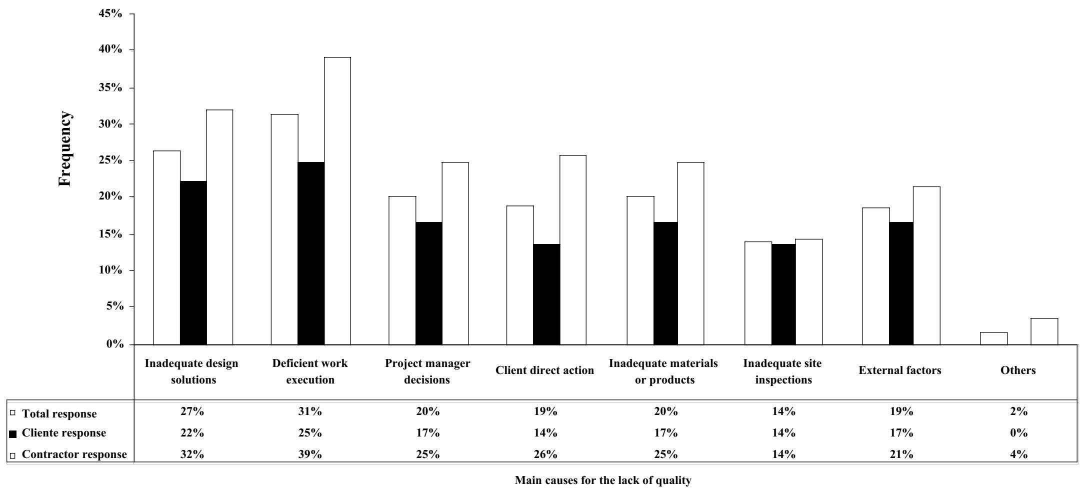
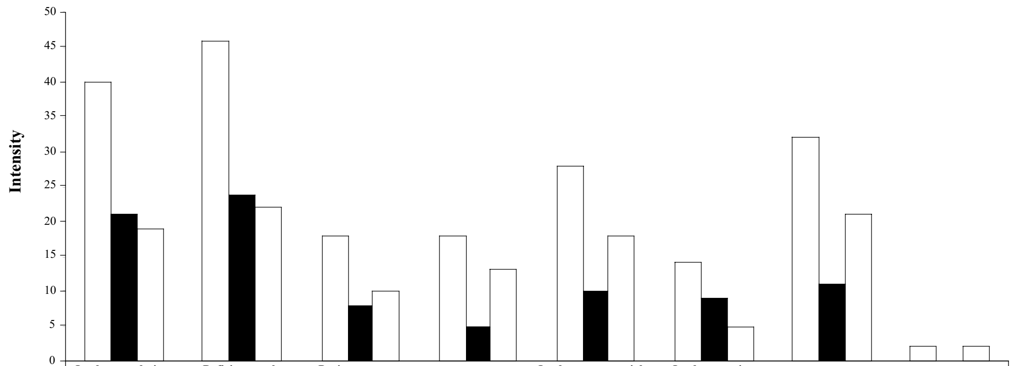


Figure 7: Frequency of causes for the lack of quality

As for the intensity of these causes, poor work execution and inadequate design solutions are more emphasized with 46 and 40 points, respectively. Clients maintain the preceding rank but with less intensity: poor work execution (24 points) and inadequate design (21 points). Contractors also weighed these causes with approximately the same intensity as clients along with external factors (21 points) and inadequacy of materials/products (18 points). Figure 8 illustrates these aspects.



	Inadequate design solutions	Deficient work execution	Project manager decisions	Client direct action	Inadequate materials or products	Inadequate site inspections	External factors	Others
Total reponse	40	46	18	18	28	14	32	2
Client response	21	24	8	5	10	9	11	0
Contractor response	19	22	10	13	18	5	21	2

Main causes for the lack of quality

Figure 8: Intensity of causes for the lack of quality

CONCLUSIONS

Results from an ongoing research project on the lack of achievements of the cost, time, safety and quality management functions in the Portuguese construction sector have been reported. These results are an outcome of a survey to the industry involving clients and contractors but the number of replies obtained was bellow expectations, therefore limiting their significance.

The results of the survey on project delays indicate that both clients and contractors agree that major causes have to do with client responsibilities and designer responsibilities followed by inadequate construction management (for clients) and project specifics (for contractors).

Both clients and contractors ascribe major causes to design errors, different site conditions and direct change orders as the main causes for cost overruns.

Lack of specific training, insufficient task preparation, lack of individual protection and the high risk of the activities are the main reasons pointed out for the lack of safety. Contractors indicate the high risk of the activities as the major cause for the lack of safety while clients blame contractors for the lack of specific training and insufficient task preparation.

Poor work execution and inadequate design solutions are the most ascribed reasons by clients and contractors for the lack of quality. External factors and the use of inadequate materials or products have also been pointed out by contractors.

Further results and proposed measures to improve achievements in the cost, time, safety and quality management functions, positively influencing the competitiveness of the Portuguese construction industry, will be presented. The results of this research will be used to establish a set of recommendations for achieving better performance of the industry.

REFERENCES

Atkinson, R (1999) Project management: cost, time and quality, two best guesses and a phenomenon, its time to accept other success criteria. *International Journal of Project Management*, **17**(6), 337–42.

Chan, A and Chan, A (2004) Key performance indicators for measuring construction success. *Benchmarking: An International Journal*, **11**(2), 203–21.

FCT Science and Technology Foundation (2006) *Reasons for lack of accomplishment of schedule, costs and safety objectives in construction*, June 2006 (in Portuguese).

Flanagan, R *et al*. (2005), *Measuring Construction Competitiveness in Selected Countries*, Final Report, University of Reading, London.

IGT Inspecção Geral do Trabalho / General Labour Inspection (2007) Acidentes Mortais de 2003 a 2007. Available online: http://www.igt.gov.pt (accessed 1 February 2007).

Moura, H and Teixeira, J C (2006), Why can't main project management functions be achieved in most construction projects? *In: 1st ICEC & IPMA Global Congress on Project Management*, Cankarjev dom Congress Centre, Ljubljana, Slovenia, 24–6 April.

OA Ordem dos Arquitectos/Board of Architects (2006) *Ordem vai trabalhar com tribunal de contas*, 27/07/2006. Available online: http://www.arquitectos.pt/?no=101004108:072006 (accessed 1 February 2007).

OE Ordem dos Engenheiros/Board of Engineers (2006) *Recomendações da Ordem dos Engenheiros para redução dos desvios de custos e de prazos nas empreitadas de obras públicas*, September, Lisbon.

Ofori, G (2003) Frameworks for analysing international construction. *Construction Engineering and Management*, **21**, 379–91.

Porter, M E (1990) *The competitive advantage of nations*. London: Macmillian.

Reinaud J (2005) *Industrial Competitiveness under the European Union Emissions Trading Scheme.* IEA Information paper, February.

FORECASTING THE HONG KONG CONSTRUCTION DEMAND – A PILOT STUDY

Ryan Y.C. Fan,[1] S. Thomas Ng and James M.W. Wong

Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong

The construction industry is one of the main pillars of Hong Kong's economy. In recent years, however, the demand for construction activity has been changing dramatically, in terms of both volume and market structure. These changes in the construction industry, together with the rapid economic growth and liberalization of markets in mainland China and Macau, have had a serious impact on both the level of activity and type of work available to the construction. Forecasting construction demand in Hong Kong, therefore, has been recognized as an important indicator for industry development and for various industry stakeholders to formulate their short to medium-term procurement strategies and corporate development plans. This paper aims to present succinctly the trends of various construction activities in Hong Kong, and discuss preliminary findings of an ongoing research study on predicting the Hong Kong construction demand. Relevant forecasting methodologies and rationale for building demand-forecast models are explored via an extensive literature review. Empirical analysis and robust modelling will be undertaken in order to generate reliable construction demand forecast for the industry. The research findings of this study are expected to capture the output behaviour of the local construction industry and that of each sub-sector for facilitating the industry's sustainable development.

Keywords: forecasting, construction demand, construction industry, Hong Kong.

INTRODUCTION

The construction industry has long been one of the main pillars of Hong Kong's economy. It essentially serves as a regulator of an economy, and its importance and impact to the economy is undeniable (Ball 1988). However, it is well recognized that construction industry is volatile and may fluctuate dramatically according to the general economic conditions (NEDO 1978; Hillebrandt 2000). The fluctuations in the level of construction output can cause significant rippling effects to the economy (Chan 2001).

The Hong Kong's construction market has indeed experienced severe recession after the Asia region being profoundly hit by the economic turmoil in 1997. Despite seeing signs of recovery lately, the future of the industry remains rather uncertain. The industry lacks a coordinated effort to monitor changes in existing market and predict future demand for construction thus resulting in an imbalanced and distorted production capacity. Construction-related organizations need to respond to fluctuating market demand to survive, and work within a tradition of competitive tendering and small profit margin (Soetanto *et al*. 2006).

It is therefore valuable to develop forecasting models using statistical techniques to predict the construction demand in the next 3–5 years, so that both policy-makers and industry practitioners can formulate appropriate short to medium-term strategies to

[1] h0389349@hkusua.hku.hk

cope with any undue fluctuations in construction. A number of reports scrutinizing the performance of the sector (e.g. Egan 1998; Hampson and Brandon 2004) have also called for the industry to extend their orientation by looking ahead and to prepare themselves to respond to potential future events and trends.

This paper presents preliminary findings of an ongoing Hong Kong construction demand forecasting study. First is a review of the current situation of the Hong Kong construction industry. A theoretical framework is then proposed to account for recent developments and possible future trends. Following that, the need for construction demand forecast is discussed, and suitable forecasting methodologies are evaluated. The expected findings for the study are highlighted before the concluding remarks.

OVERVIEW OF HONG KONG CONSTRUCTION INDUSTRY

According to the Census and Statistics Department (C&SD) of the HKSAR Government, the construction industry produced a total gross value of work of nearly HK$90 billion in nominal terms in 2006, accounting for around 6% of total local Gross Domestic Product (GDP). It ranked third in terms of percentage contribution to total GDP from 1980 to 2004, after the largest services sector and the manufacturing sector. During the third quarter of 2006, the construction industry in Hong Kong employed more than 280,000 people, representing 8.1% of total labour force.

Residential building construction output was about HK$15.5 billion (at current market price) in 2006. Other buildings, including commercial, industrial and storage, and service buildings added up to a similar gross value of HK$13.9 billion. The value of work in civil engineering sector was over HK$12.3 billion, while the value of non-site activities (including decoration, repair and maintenance, construction work at minor work locations, carpentry, electrical and mechanical fitting, plumbing and gas work etc.) was over HK$48.3 billion. The four categories contributed approximately 17%, 15%, 14% and 54% respectively to the total construction output in 2006.

The general construction industry not only provides strong value added to the local economy, but also supports the economy by high level of consumption. The building and civil engineering establishments consumed over HK$30 billion in materials and supplies, fuels, electricity and water, and maintenance services in 2005. The real estate development, leasing, brokerage and maintenance management establishments and architectural, surveying and project engineering establishments spent over HK$10 billion and HK$200 million on the same items respectively.

Most of the construction companies in Hong Kong are small in size, as 82% of the total establishments in building and civil engineering discipline were producing less than HK$5 million of turnover in 2005. These small companies hired only 37% of total workforce in the discipline though, while a substantial portion (about 30%) of workforce was engaged in companies producing work valued at more than HK$100 million in 2005 (Census 2005b).

In addition, Hong Kong has been exporting its construction and engineering services to overseas markets, especially China and Macau, primarily due to the shrinking local construction expenditure. In 2005, the export of construction services alone was almost HK$2.5 billion, along with over a billion dollars export in architectural, engineering and other technical services. Of which, all the construction services were exported to Asian countries, whereas majority of architectural, engineering and other technical services were exported to Asia (i.e. 88%), with the rest to North America, Western Europe, Australasia and Oceania (Census 2005a).

RECENT TRENDS

Hong Kong was one of the countries being profoundly hit by the Asian economic turmoil in 1997. Its GDP growth rate at constant market price once became negative since 1998. The recession propagated through all business in Hong Kong and, inevitably, the construction industry was also severely affected. The construction output has been declining since 1998 (Figure 1). The total construction work volume has shrunk by over 30% in 2006 compared to its peak in 1997. The decrease in the percentage contribution to the total GDP (Figure 2) made the construction sector being overtaken by the electricity, gas and water sector and only ranked fourth in terms of importance among all sectors in 2005, for the first time since 1980.

The construction site works, both the public and private projects, followed a declining pattern in the last few years. However, the non-construction site works, representing the repair and maintenance sector, has been on an upward trend since 1980s. The sector climbed even faster since 2004, while the other sectors of construction industry were still deeply caught in the recession.

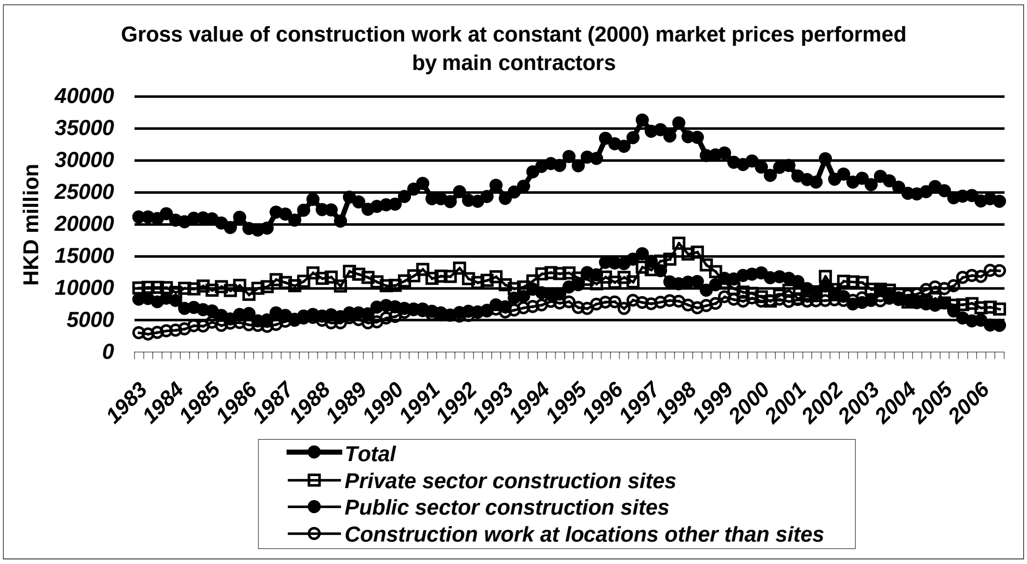


Figure 1: Quarterly gross value of HK’s construction work at constant (2000) market prices (Source: Census and Statistics Department)

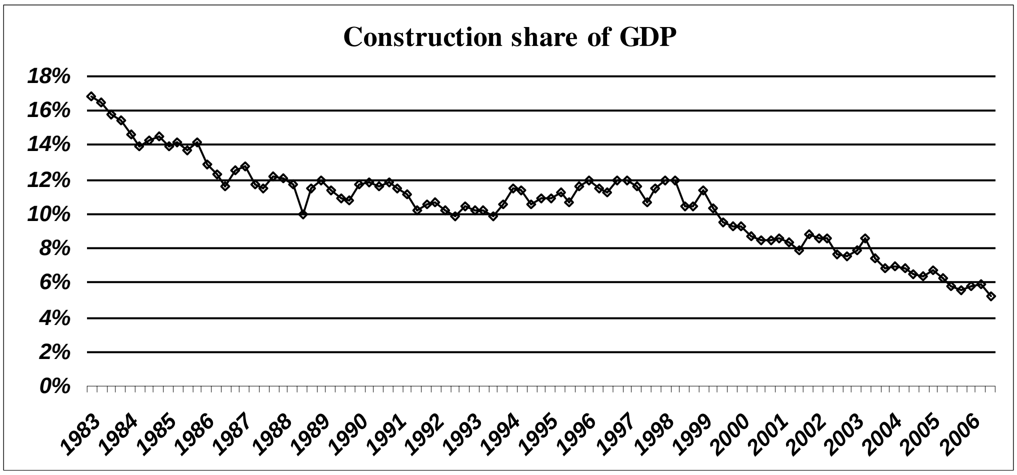


Figure 2: Contribution of Hong Kong’s construction activity to GDP (Source: Census and Statistics Department)

THE OUTLOOK

Bon (1992) discussed the changing role of the construction sector in different stages of economic growth. He pointed out that both the construction sector's contribution to the countries' GNP as well as the absolute construction volume would follow an inverted U shape as a country moves from being a less developed country (LDC) to newly industrialized country (NIC) and finally to advanced industrial country (AIC). His ideas were reflected in Figures 3 and 4.

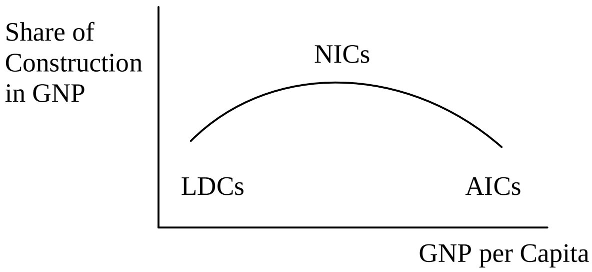


Figure 3: Share of construction in GNP vs. GNP per capita (Source: Bon 1992)

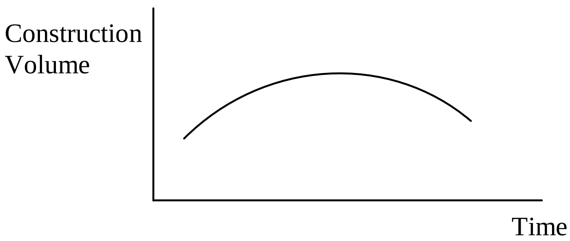


Figure 4: Construction volume over time (Source: Bon 1992)

Bon also suggested that, as time moves on, the repair and maintenance sector and some new construction work would eventually form the lower bound of the declining half of the U-shape curve, which is obvious because the capital stock that generally built in the early stages of economic growth tends to age over time. The model holds for any one country over time, as Bon stated, since economic development is unidirectional and must go through the three stages mentioned above.

It is not difficult to match the Hong Kong's situation with the Bon's model. The GDP growth rate has slowed down in 1990s while services sector contributed to the total GDP for more than 90% in 2005, indicating Hong Kong's transformation into an AIC. The construction sector's contribution to GNP (GDP is identical to GNP for non-tradable goods such as construction goods, according to Bon) and the construction output have more or less followed an inverted U-shape (Figures 1 and 2).

The repair and maintenance sector is gradually taking up a larger portion of the total construction output. Hence, the construction demand and output in Hong Kong may continue to shrink as Hong Kong moves gradually towards economic maturity. An accurate forecast on the future construction demand in the next 3–5 years will be able to better illustrate the trend, hence preparing the local industry for the coming challenges.

THE RESEARCH FRAMEWORK

In view of the recent slump experienced by Hong Kong construction industry as well as the various calls for better insight into future construction trend, a research study that aims to forecast the Hong Kong construction demand is being carried out. The research adopts statistical means, of which will be explained below, to establish a rigorous forecasting models suitable for the local situation. The models built are expected to capture the future demand pattern for Hong Kong construction industry in each of the detailed sector such as residential/commercial/industrial in medium to long-run, based on the historical trend as well as the contributing social and economic factors. The predicted future pattern will then be compared with the model suggested by Bon (1992). The identified contributing factors to construction demand will help verify the demand theories proposed by various scholars (e.g. Ball 1998; Hillebrandt 2000). These theories will finally be combined and modified to illustrate the Hong Kong situation.

CONSTRUCTION DEMAND FORECASTING

Construction demand forecast studies have been carried out in many countries. For instance, Goh (1999) forecasted for sectoral construction demand in Singapore using a multi-regression model, while another model using Box-Jenkins approach for the forecast of construction industry demand, price and productivity in Singapore was built by Goh and Teo (2000). Akintoye and Skitmore (1994) predicted the UK private sector construction demand by building multi-regression models using quarterly output data. Tang *et al*. (1990) adopted regression technique to forecast the total construction activities in Thailand. In the US, Killingsworth (1990) developed a demand-forecasting regression model for industrial construction.

Causal forecasting approach and time-series models are indeed the most common techniques for the forecasting of construction demand. To produce a more accurate and meaningful forecasting model, construction demand should be further classified into detailed categories of residential/commercial/industrial construction demand, building/civil/repair and maintenance works demand, public/private sector construction demand, etc., so that the specific contributing factors accounting for each of the category can be selected and the uncertainties in future trend can be minimized (Goh 1999).

Amongst the available causal forecasting approaches, the regression model is the most common and versatile causal technique, applicable in every facet of business decision-making, due to its relative simplicity in both the concept and application (Goh 1999). The regression model also has its strengths in outlining the contributing factors towards the variable being studied and, hence, allowing a more comprehensive theoretical framework to be established. On the other hand, it means that information on the possible contributing factors needs to be gathered and a selection process of the more influential factors is involved. Lack of information can be critical and intuitive judgment involved while selecting parameters for the final model may contribute to discrepancies in the final model. Therefore, all possible contributing factors affecting construction demand will be identified prior to the model building. Factors considered by previous literature are summarized below.

FACTORS AFFECTING CONSTRUCTION DEMAND

A brief summary of the factors being considered in previous literature for forecasting construction demand is shown in Table 1. Not all of these factors were found to be significant in the final models of the literature of where they are extracted. However, as the construction market is unique in each country, these possible factors should be considered and carefully selected when developing the regression models.

The reviewed literature usually distinguishes construction demand by residential/industrial/commercial/public utilities/repair and maintenance sectors. Akintoye and Skitmore (1994) focused their study on the private sector construction demand only, while the other scholars included both public and private sector works in their analysis. For residential construction demand, population, interest rates and construction approval/completion/transaction volume were the most commonly considered factors. National economy indicators like GDP, tender price index and unemployment rate were also used in some models.

Table 1: Factors affecting construction demand

	Residential Demand	Industrial Demand	Commercial Demand	Public Utilities Demand	Repair and Maintenance Demand
Population Structure	O, TA, G, TS, H	K, G	O	O, H	
GDP, GNP, National Income	TA, A	TA, A, G, H	TA, A, G		H
National/Corporate Savings	G	TA, G	TA, G		
Government revenue/expenditure				O, TA, H	
Interest Rate	O, TA, A, TS, H	K, A, G	A		
Export Value		TA, B, G	TA, B		
Tender Price Index	A, G	A	A		
Labour Cost Index		G			
Income	O, H				H
Housing Loans	G, H				
Property Price	O, TS	B	B		
Land Price			O, G		
Consumer Price/Spending	TA	B	B		O
Money Supply		G			
Employment/Unemployment Rate	A, G, H	A, B, G	O, A, B		
Orders for plant and equipment		K, O, H			
Productivity		G	G, H		
Composite index of leading indicators		K, G			
Construction approval/completion/transaction	O, TA, G, TS	K, G	G	TA	O
Industrial/Manufacturing output/investment/utilization rates	A	K, O, TA, A, B, G, H	TA, A, B	H	
Manufacturing/Trade/Retail Sales		K	G, H		
Visiting Tourists		TA	TA		

Note: K=Killingsworth (1990); O=Ofori (1990); TA=Tang *et al.* (1990); A=Akintoye and Skitmore (1994); B=Ball *et al.* (1998); G=Goh (1999); TS=Tse *et al.* (1999); H=Hillebrandt (2000)

For industrial construction demand, national economy indicators and the performance of the manufacturing and industrial sector were the most popular factors considered.

Population, national savings, interest rate, export performance, unemployment rate and orders for plants and equipments were the less mentioned factors. For commercial construction demand, national economy indicator, employment distribution and industrial sector performance were the more prevailing factors, while national savings, export value, land price, productivity and sales were considered as well.

When forecasting for public works and utilities, government revenue and expenditure was the most important factor while population structure was also incorporated into the models. For repair and maintenance work, as it was seldom being considered in previous studies only a few factors including national economy performance, household income, purchasing power and new construction completion which may all have impact on the level of work in the sector were considered.

TIME SERIES MODELLING TECHNIQUES

Time-series models, in contrast, predict the future values of a time series solely based on the historical trend of the variable. It treats the underlying trend of the series as a "black box" and makes no attempt in trying to discover the factors contributing to the trend (Goh and Teo 2000). In other words, a time-series model attempts to describe the random nature of the process, which is also known as the stochastic process of time series that generated the observations of the variable being studied (Pindyck and Rubinfeld 1998).

As the model assumes repetition of similar patterns over time, it is only suitable for short-term forecasting (Goh and Teo 2000; Wong 2006) and large forecast errors may arise if discontinuities occur within the projected time period (Wong 2006). Despite these constraints, the time-series model is considered an accurate model due to its emphasis on investigating the stochastic process of the variable rather than adopting a deterministic approach.

The simplest form of time-series modelling is to fit the data series by the exponential smoothing technique (Ng *et al*. 2004). Bowerman and O'Connell (1993) described the method as "not based on any formal statistical model or statistical theory". The intuitive model is studied below; as a test of whether more sophisticated methodology would be needed for the construction demand forecasting study. The model describes the time-series by the no trend equation

$$y_t = \beta_0 + \varepsilon_t \tag{1}$$

where β_0 can be represented by the least point estimate, i.e. the mean of y_t for $t = 1 \ldots n$, being denoted $a_0(0)$.

Hence, the update of estimate from $a_0(T-1)$ to $a_0(T)$, in a time period T, can be obtained by using the smoothing equation of

$$a_0(T) = \alpha y_t + (1-\alpha)\, a_0\,(T-1) \tag{2}$$

where α is the smoothing constant being selected between 0 and 1 following a iterative process to minimize the model's sum of squared errors; and α represents the rate of the previous observations of also represents the rate that the older observations of y_t being dampened out of the current estimate of β_0 as time advances.

In other words, for α closer to 1, the remote observations are dampened out quickly and the recent observations would be weighted more heavily in estimating β_0.

Applying exponential smoothing technique in predicting construction demand

The time-series data of the gross value of total construction work, the gross value of public sector construction site work and the gross value of private sector construction site work, all at constant year 2000 market prices, were computed for modelling. The quarterly data from 1983 to 2005 were used, representing a total of 92 data points. The earlier 80 quarterly data points from the first quarter of 1983 the fourth quarter of 2002 were fitted into the model to produce forecast values for the next 12 periods, i.e. quarterly construction output from the first quarter of 2003 to the fourth quarter of 2005.

The forecast values were then compared to the actual data of the same period, by using the Mean Absolute Percentage Error (MAPE). Wong *et al.* (2005) suggested using the MAPE for testing time series models and recommended using 10% as the acceptable level of accuracy. The MAPE is computed as follow:

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{Y_t - F_t}{Y_t}\right| \times 100 \qquad (3)$$

where Y_t is the actual value of the series at period t; F_t is the forecast value at period t; and T is the total number of periods.

The developed exponential smoothing models are summarized in Table 2. Despite the high significant levels for the α parameters that were found, it should be noted that the α values ranged from 0.67 to 1. The result calls for methods other than the exponential smoothing to be adopted to forecast the time series. As Bowerman and O'Connell (1993) pointed out, if the α value exceeds 0.3 the current model may not be appropriate or the parameter β_0 may be changing quickly over time. On top of that, the models, especially for the more detailed categories of construction demand such as the public sector output and private sector output, do not perform satisfactorily in terms of MAPE. The MAPE becomes even larger when the longer term forecast values were compared with the actual ones.

Table 2: Results of simple exponential smoothing model by JMP

Forecast variable	α	**MAPE (%)**
The Gross Value of Construction Work as constant (2000) market prices (A)	0.67	7.05
The Gross Value of Public Sector Construction Site Work at constant (2000) market prices (B)	1	15.47
The Gross Value of Private Sector Construction Site Work at constant (2000) market prices (C)	0.82	32.08

It supports that simple exponential smoothing technique might be adequate only for short-term forecasting. For medium to long-term forecasts involving predicting values more than three years ahead, such as our Hong Kong construction demand forecast study, the exponential smoothing technique may not be the best choice (Table 3). Furthermore, Ng *et al.* (2004) discussed another major shortcoming of simple exponential smoothing technique being the method's assumption of uncorrelated errors, which in turn means that observations over time are uncorrelated. While collecting time-series data in practice, serial correlation is often anticipated.

Table 3: Absolute percentage errors for the forecast and out-of-sample data points

Out-of-sample data	A	B	C
2003Q1	3.62	11.1	3.67
2003Q2	1.45	11.1	19.7
2003Q3	1.29	12.8	10.5
2003Q4	5.13	20.5	5.4
2004Q1	9.15	40.0	4.3
2004Q2	9.63	38.2	0.8
2004Q3	8.02	39.3	3.9
2004Q4	4.66	29.8	6.6
2005Q1	7.32	42.0	1.9
2005Q2	12.4	48.8	21.9
2005Q3	11.3	47.9	47.0
2005Q4	10.8	43.6	60.2

Therefore, a more sophisticated model with a strong theoretical background is recognized as crucial for forecasting construction demand. Among all the possible models, Goh and Teo (2000) confirmed the accuracy of the Box-Jenkins approach in handling construction demand forecasting. The Box-Jenkins approach has been regarded as an accurate, reliable and widely applicable time-series model by researchers (e.g. O'Donovan 1983; Wheelwright and Makridakis 1985; Goh and Teo 2000; Ng *et al*. 2004). Bowerman and O'Connell (1993) introduced the Box-Jenkins methodology as an iterative procedure involving the transformation of data series into a stationary and non-seasonal series for the Auto-Regressive Integrated Moving Average (ARIMA) modelling process. The tentative model is then evaluated for its goodness of fit against the historical data using the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Maddala 2001). Should the tentative model be acceptable in fitting accuracy, the process would be repeated with different models until a satisfactory model is identified. Forecast of the data series will then be produced based on the final model.

FUTURE WORK

The present research study aims to forecast for Hong Kong's construction demand, classified into categories of residential/commercial/industrial construction demand, building/civil/repair and maintenance works demand as well as public/private sector construction demand. The classification will be as detailed as possible, depending on the availability of data. Multi-regression models and time-series models will be built for each of the classification and compared with historical data by error estimators to ensure their accuracies. A combination of the two models may be proposed, as Ng *et al*. (2004) reported in their study that the combined regression analysis and time series model outperformed each of the individual one. The results are expected to offer a better picture to the local industry about the future work volume and distribution of workload in each discipline, such that the policy-makers and industry practitioners can formulate strategies to find sustainable work source.

Apart from being practically informative, the regression model shall provide evidence for establishing theory of construction industry supply and demand in the local context. The technique can also be compared to the time-series model in terms of forecasting accuracy, as most of the earlier construction demand forecast studies were based on the regression techniques. Furthermore, a combined model involving the two approaches has not been applied in construction demand forecast before. Hence, it is worth investigating the possibility of developing a new direction for construction demand forecasting. Lastly, forecasting repair and maintenance works has not been extensively conducted before, and hence the study will also attribute to verify the suitably of demand theories as proposed by scholars (e.g. Ofori 1990; Hillebrandt 2000) in various sub-sectors.

CONCLUSIONS

Hong Kong's economy has been suffering from a deep recession since 1997. The Asian economic turmoil and overheated property market contributed to a sharp downturn from the earlier economic boom in 1990s. There are evidences suggesting that Hong Kong has transformed into a rather mature economy in which the services sector would become the most important economic pillar while the construction industry fades out. Together with a slow down in population growth rate, Hong Kong's construction industry may inevitably be going through a structural change. The impact from the recession in construction sector could further propagate to other sectors as construction sector has extensive connection with a lot of other sectors. The plunging construction volume has not been showing signs of stabilizing yet. Despite the rather discouraging signs, scholars have suggested that there will be a growing demand for repair and maintenance, together with some new construction orders, to sustain the construction industry. On top of these works, the industry may seek alternative opportunities, for example the overseas markets or other construction-related business, to find sustainable paths for growth.

Under such a severe situation, the construction demand forecast can serve as an important guideline when planning for the construction companies' operations as well as formulating future business strategies. Government can arrange its public investment in a way that provides maximum benefit and minimal disturbance to private sector developments. Having a foresight into future construction market is also important to avoid being caught up in possible recessions. Before building the forecast models, construction demand data are collected and classified into various disciplines by job nature. Multi-regression and time-series model are both adopted. Possible underlying factors affecting construction demand considered in previous multi-regression models have been summarized, and similar Hong Kong data will be collected. A simple exponential smoothing technique has been studied and proven insufficient in precisely forecasting for short to mid-term construction demand. Hence, the more sophisticated Box-Jenkins model is proposed for carrying out time-series analysis. The two models may be combined, if the integrated model can provide better performance than any of the individual ones. It is anticipated that the study will capture Hong Kong's construction demand in different disciplines during the next 3–5 years.

ACKNOWLEDGEMENT

The authors are grateful to the Construction Industry Institute – Hong Kong for funding this study. Financial support from The University of Hong Kong through its CRCG Seed Funding for Basic Research (grant no. 10207434) is also gratefully acknowledged.

REFERENCES

Akintoye, A and Skitmore, M (1994) Models of UK private sector quarterly construction demand. *Construction Management and Economics*, **12**(1), 3–13.

Ball, M (1988) *Rebuilding Construction: Economic Change and the British Industry*. London: Routledge.

Ball, M, Lizieri, C and MacGregor, B D (1998) *The Economics of Commercial Property Markets*. London: Routledge.

Bowerman, B L and O'Connell, R T (1993) *Forecasting and Time Series: An Applied Approach*. 3Ed. California: Duxbury Thomson Learning.

Census and Statistics Department (2005a) *Report on Hong Kong Trade in Services Statistics for 2004*, Government of Hong Kong Special Administrative Region.

Census and Statistics Department (2005b) *Report on 2005 Annual Survey of Building, Construction and Real Estate Sectors*, Government of Hong Kong Special Administrative Region.

Census and Statistics Department (2006) *Quarterly Report on General Household Survey*, Government of Hong Kong Special Administrative Region.

Chan, S L (2001) Empirical test to discern linkages between construction and other economic sectors in Singapore. *Construction Management and Economics*, **19**(4), 355–63.

Chatterjee, S and Hadi, A S (1988) *Sensitivity Analysis in Linear Regression*. New York: John Wiley & Sons.

Egan, J (1998) *Rethinking Construction*, Report of the Construction Task Force. London: HMSO.

Goh, B H (1999) An evaluation of the accuracy of the multiple regression approach in forecasting sectoral construction demand in Singapore. *Construction Management and Economics*, **17**(2), 231–41.

Goh, B H and Teo, H P (2000) Forecasting construction industry demand, price and productivity in Singapore: the Box-Jenkins approach. *Construction Management and Economics*, **18**, 607–18.

Hampson, K and Brandon, P (2004) *Construction 2020: A Vision for Australia's Property and Construction Industry*, Cooperative Research Centre for Construction Innovation, Brisbane, Australia.

Hillebrandt, P M (2000) *Economic Theory and the Construction Industry*. London: MacMillan Press Ltd.

Killingsworth, Jr. R A (1990) Preliminary investigation into formulating a demand forecasting model for industrial construction. *Cost Engineering*, **32**(8), 11–15.

Maddala, K (2001) *Introduction to Econometrics*. England: John Wiley & Sons Ltd.

National Economic Development Office (1978) *How Flexible is Construction? A Study of Resources and Participants in the Construction Process*. London: HMSO.

Ng, S T, Cheung, S O, Skitmore, M and Wong, T C Y (2004) An integrated regression analysis and time series model for construction tender price index forecasting. *Construction Management and Economics*, **22**, 483–93.

O'Donovan, T M (1983) *Short Term Forecasting: An Introduction to the Box–Jenkins Approach*. New York: Wiley.

Ofori, G (1990) *The Construction Industry: Aspects of its Economics and Management*. Singapore: Singapore University Press.

Pindyck, R S and Rubinfeld, D L (1998) *Econometric Models and Economic Forecasts*. 4ed. USA: The McGraw-Hill Companies, Inc.

Soetanto, R, Harty, C, Goodier, C, Austin, S, Dainty, A, Price, A and Thorpe, A (2006) Does the construction industry have a future? *17th International ECI Conference*, Global construction ten years on: adapting to change, 23–24 March 2006, Delft.

Tang, J C S, Karasudhi, P and Tachopiyagoon, P (1990) Thai construction industry: demand and projection. *Construction Management and Economics*, **8**(3), 249–57.

Tse, R Y C, Ho, C W and Ganesan, S (1999) Matching housing supply and demand: an empirical study of Hong Kong's market. *Construction Management and Economics*, **17**, 625–33.

Wheelwright, S C and Makridakis, S (1985) *Forecasting Methods for Management*. 4ed. New York: Wiley.

Wong, J M W, Chan, A P C and Chiang, Y H (2005) Time series forecasts of the construction labour market in Hong Kong: the Box-Jenkins approach. *Construction Management and Economics*, **23**, 979–91.

Wong, J M W (2006) *Forecasting manpower demand in the construction industry of Hong Kong*, unpublished PhD dissertation, The Hong Kong Polytechnic University.

FROM DEMAND-DRIVEN SUPPLY TOWARDS SUPPLY-DRIVEN DEMAND IN CONSTRUCTION

Hennes De Ridder[1] and Ruben Vrijhoef

Faculty of Civil Engineering, Delft University of Technology, Delft NL-2600 GA, The Netherlands

The ‘living building’ concept (LBC) represents a new approach to the delivery and life cycle of built objects. The idea of dynamic control of LBC respects the fact that the function and circumstances of built objects are constantly changing. This is in full contrast to the traditional building paradigm and current practice, which are based on a static approach to the performance of buildings. In traditional practice the demand is fixed at the start of a project and supply is only mobilized to meet the initially established requirements. This demand-driven supply results in supply of standard products and prevents innovation. LBC aims to change this into supply-driven demand involving all parties in the supply chain to supply an integrated product and dealing adequately with changing technology, regulations and demands throughout the entire life cycle of buildings. As a result the application of LBC concept reduces risks and transaction costs substantially. In order to do so the concept must be the basis for life cycle contracts. Following a previous application of LBC to a school building, LBC has recently been applied to the redevelopment of a hospital building in the Netherlands. The application of LBC has proved to be beneficial developing a facility that will be flexible to future changes, and has led to a movement from traditional demand-driven supply towards supply-driven demand, implying that the client’s demand remains on a high aggregation level, and supplying parties offering an integrated solution to this demand.

Keywords: benefit, dynamic control, life cycle, living building concept.

INTRODUCTION

Society and technology are changing continuously. This subsequently induces changes in the activities of human beings. As a result, the goods needed for human activities alter frequently owing to the modified wishes and requirements. The consumer market for goods is fully equipped to anticipate and meet such changing conditions. Products and services such as electronics, cars, bicycles and healthcare are renewed continuously. This is possible because consumers and producers are geared to one another. The essence is that demanders are meant to be surprised by the products and services provided by innovative suppliers: demand is following supply. The supply chain needs to develop activities like marketing, research, product development, branding in order to stay in touch with the consumers (De Ridder and Vrijhoef 2003).

The construction industry is totally different. The majority of people working in that sector assume that the world does not change during the lifetime of a building. This can be concluded on the basis of the trend in construction to award contracts,

[1] h.a.j.deridder@tudelft.nl

covering the outsourcing of multiple tasks like construction, design, maintenance, operation and financing, over a long period (up to 40 years) with fixed output and fixed price. In such a top-down approach the contractual parties create high risks for themselves by fixing the future, excluding both end-users as well as innovative suppliers, and giving way to financiers and lawyers as the new leading parties in the built environment. In short, to a larger extent we build structures and buildings with yesterday's technology, with today's ideas for tomorrow's people.

On the other hand, when observing the building sector more carefully, we could identify some similarities with the consumer market. Obviously, the world in and around buildings changes faster than buildings themselves. And the speed of changes increases more and more. These changes not only relate to users and stakeholders with their own respective interests on the one hand, and technology on the other. Changes also relate to climate, regulations, resources and financial/economical conditions.

For instance the changing climate will definitely lead to new standards for cooling in public buildings. The 'living building' concept (LBC) (Living Building Concept®) transforms the 'top-down' organized pull market of the construction sector into a 'bottom-up' organized push market enabling buildings to be and stay fit for purpose and up to date. In the paper the main principles of LBC will be explained and discussed.

AIM OF LBC

Construction implies complex product development in a changing context, involving many parties, delivering products with value to society, pulling high levels of resources from the economy. Construction projects often take a long time, and the life cycles of built services are lengthy. During the construction process, the level of information and knowledge grows, on the side of both the client and the supplier. Demand and supply influence each other. So requirements of buildings change over time. Demand must be adaptable and supply must grow along. Procurement and supply strategies as well as project and life cycle management arrangements must be able to cope with these dynamic mechanisms.

The rationale of LBC is based on two underlying problems in construction: perception and 'process statics'. The problem of perception is caused by the fact that the first demand specification is basically always incorrect or incomplete, because it is impossible to demand before knowing what is available and possible. Supplying without knowing what is basically wanted is impossible as well. So demand and supply are intrinsically connected, and this should be reflected in the process towards delivery of any product such as built services. However in current construction practice, this is often not the case. Demand and supply are relatively disconnected. This is basically the result of the tension between value and costs, and thus between the client's interest in added value versus the supplier's interest in profit. The problem of 'process statics' makes this worse while in most cases the construction process is fixed from the start of a project, making it impossible to cope with change effectively.

LBC aims to increase the benefit for both demanding and supplying parties, by focusing on the maximization of the gap between value and costs of the built object (Figure 1). The costs are determined by the suppliers of a built object jointly. The value includes a wide spectrum of types of value (financial, sustainable, etc.) which are determined by the client and the users in the first place, who can decide to involve a larger stakeholder group to help determine the total value. This is considered to be a dynamic process, meaning that both demanders and suppliers get involved in this process with a ‘control budget’ from both sides, which is used to find the optimal solution for additional demands collaboratively. These can fluctuate between the minimum and maximum boundaries set by both parties. The main criterion is that the additional demands and solutions proposed must have a positive effect on the benefit.

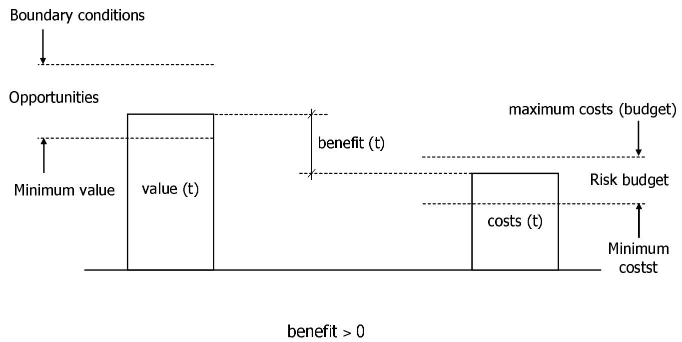


Figure 1: Essence of delivering value in the built environment

PRINCIPLES OF LBC

Partnering aimed at maximum benefit

Mostly construction is a joint activity involving multiple parties. LBC stimulates parties to find ways to maximize the collective benefit, i.e. the gap between value and costs. All parties are challenged to find solutions to either increase the value and/or decrease the costs. Ideally, the collective contributions of parties to do so must lead to a total value that exceeds the sum of values, and a total costs that is lower than the sum of all costs (Figure 2). This process is organized in a dialogue form that requires that all parties involved are open in their communications. The process as well as the information shared are monitored and checked by a third party. And in the end it is the client who decides after having consulted experts. The end result is the start of the rest of the process which is flexible and thus capable to cope with possible changes. This approach is illustrated later in this paper by an experiment applying LBC to the redevelopment project of a hospital building, which is currently ongoing.

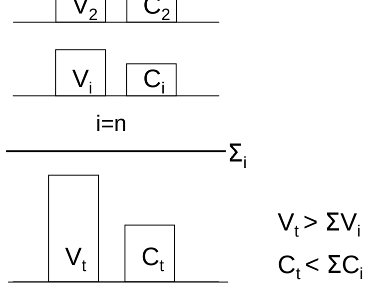


Figure 2: Basic partnering model between demanding and supplying parties

Transaction connecting value and costs

For many reasons there is always a need for some kind of change during the process, so there is a need for a dynamic approach. This is particularly true in construction. The 'natural response' in construction has been to isolate and fix various aspects as much as possible, including the price and the design early in the process. This leads to quasi-certainty, 'process statics' and disproportional additional transaction costs. Owing to this kind of fragmented and delegated control, and long demand and supply chains, changes come often too late to be effectively and systematically dealt with. Instead the total value should be interconnected qualitatively and quantitatively to the total costs by means of an algorithm between value and costs. Then demanding and supplying parties can collaborate to achieve the highest possible benefit to the mutual advantage of both demanding and supplying parties (Figure 3).

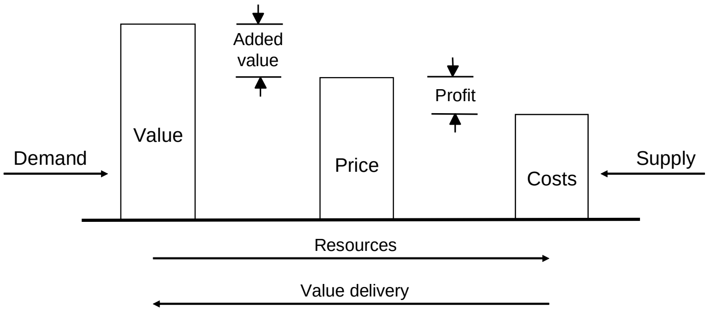


Figure 3: Basic transaction model between demanding and supplying parties

Dynamic control

Instead of enforcing the initial planned performance against a fixed price calculated in the first phase of the project, the price is based on the actually delivered performance at the end of the project. The final price goes up to the initially set maximum guaranteed price, not exceeding the planned budget of the client. The range between initial price and maximum budget is the client's 'control budget' for dealing with problems of perception and additional value to be delivered during the process. In addition, the contractor is able to reserve budget for investments to reduce costs or increase value (Figure 4). This approach can be defined for the project only, but can be extended to the whole life, and can be applied to a variety of contract formats, from build-only contracts to more integrated DBFMO contracts (design, build, finance, maintain, operate).

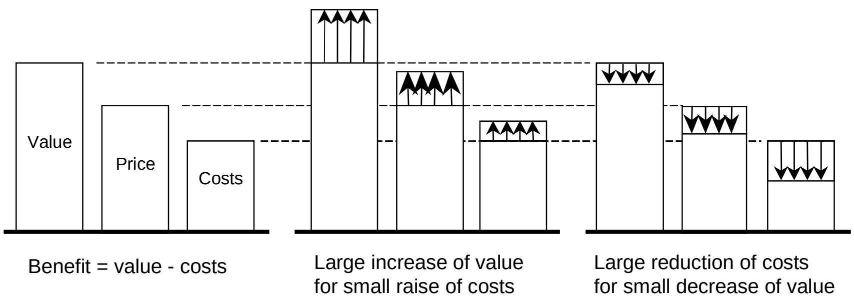


Figure 4: Dynamic control strategies to increase the total benefit

Consumer market approach
In contrast to the construction market, consumer markets consist of consumers and producers. Producers develop and sell products proactively anticipating the wishes of consumers. In construction, broadly, there are contractors and clients. Normally, clients start a project, and contractors build it based on the client's design. The concept of LBC represents a consumer market approach to construction. In those terms, consumers in the construction industry are interested in value for money. That means that they get value and spend money for it. Their requirements and wishes are highly dependent on what producers have to offer. As the offer changes, the requirements and wishes change as well. Producers in the construction industry are interested in money for value. That means that they generate value and get money. The value to be produced against the price is the core of competition and is subject to change due to innovation. Bottom-up organized supply chains consist of partners, which use research and development to generate supplier specific systems. These supply chains and use branding and marketing in order to know the consumers' wishes and satisfy their demands proactively (Figure 5).

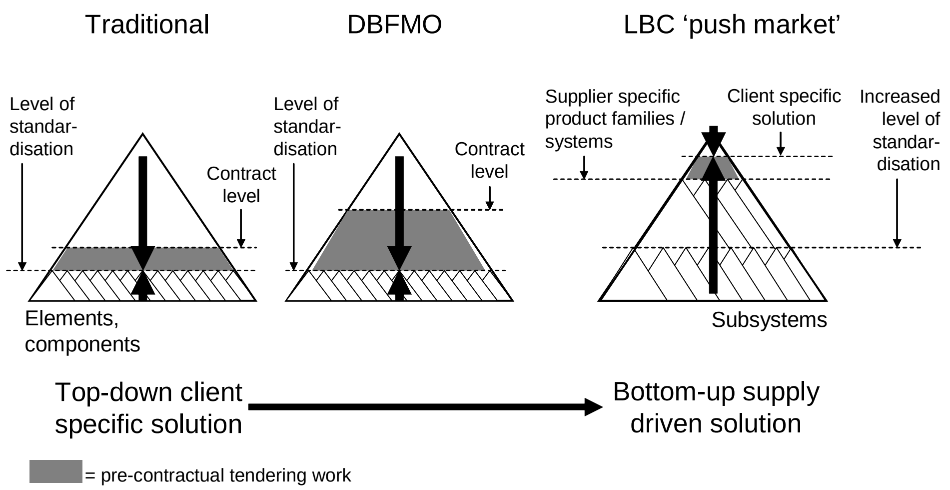


Figure 5: From demand-driven supply towards supply-driven demand

DEMAND AND SUPPLY STRATEGIES OF LBC

Demand strategy
Particularly in the public sector many clients have fixed and restrictive budgets, and public projects are subjected to investigation by government agencies to ensure value for money, control over public funds and public interest in general. Within LBC the client's budget, public or private, is always higher than the price and includes a buffer for dynamic control by the client. The supplier (e.g. contractor) sets an initial price for the basic solution and the possible scenarios. The buffer between the budget and the price is used for unforeseen changes: changing demands, requirements, regulations, standards, technology, finance, etc. The following procurement process is based on a continued process of 'price development': it starts with an initial price for initial design, through a final price for actually measured additional output at the moment of delivery, and next constant measurement of delivery of life cycle value. This process can be capped, e.g. by means of a guaranteed maximum price, which in

this case equals the budget set at an earlier stage. Similar concepts of target price, guaranteed maximum price and budget allowance for extra risks and changes have been introduced previously (e.g. Boukendour and Bah 2001; Cain 2003).

Hence the lowest price is not necessarily the client's main selection criterion and driver. Rather it is necessary to realize that the price has to be related to the value delivered in a constant manner, and value for money has to identified, to ensure that clients get the best possible life cycle value from suppliers (contractors, etc.) (Wong *et al.* 2000). However, in current practice, criteria for selection and bid evaluation of contractors are often still aimed at mere project delivery capabilities. For LBC, a wider range of criteria is needed to evaluate suppliers' capabilities against the needs of clients and other stakeholders (Hatush and Skitmore 1997). Thus the procurement system must be linked to the client's priorities. The priorities and the procurement system are influencing the team selection, and thus the project outcome and performance level (Kumaraswamy and Dissanayaka 1998). The use of 'sound' selection criteria and application of a 'best value based contractor selection framework' are essential to achieve the desired project outcome and 'best value' (Luu *et al.* 2003).

In a dynamic approach, the client will not put a lot of effort into a complete formulation of the demand and fixation of the price in an early phase of the project, but rather starts with setting boundary conditions, defining the 'procurement space' for an adequate solution to be delivered by the contractor. Negotiation and collaboration have been advocated rather than competition and relying on market mechanisms to achieve best value for money. However, it has also been argued that competitive procurement methods achieve better value for money than negotiated procurement methods (Abrahams and Farrell 2003).

Supply strategy

Most supply strategies in construction are restricted to project delivery only. Few advanced supply strategies are extended beyond project delivery, including facility management, maintenance and refurbishment, to ensure the functionality and serviceability of the built service. This implies 'continuous value delivery' or 'life cycle value delivery', instead of project delivery. This approach requires dynamic control capabilities of the whole life cycle by suppliers of built objects, and parts of those objects. The industry needs to broaden its approach to value delivery, and apply the concept of value delivery proactively vis-à-vis construction clients (Thomson *et al.* 2003). In general, LBC requires the industry to move from a delivery system within a price-based environment towards higher level of performance-based competition (Parmar *et al.* 2004).

Industry partners must adopt the use of integrated value delivery to facilitate collaborative working to resolve current industry inadequacies regarding design, construction and facility management (Austin and Thomson 1999). Integration of the team to the client's value system is essential to capture client value from the beginning of the project and informing further decision making during the project, and continued value delivery through the value chain (Kelly and Male 2001). Therefore, contractors and other suppliers in construction must develop and improve their marketing strategies, their costing capabilities and their financial risk management (Xu and Tiong 2001). This must result in advanced supply strategies ensuring the positive balance between price and costs.

DYNAMIC OUTSOURCING AND PARTNERING APPROACH

In construction, projects often start with the arrangement of legal matters in order to prevent claims and disputes. After that the organizational issues with regard to the project are arranged, and then the relationship between parties is established. LBC is based on a reverse sequence. It starts with the relationship between parties, then the organizational issues and finally the legal aspects are arranged. This means that partnering comes first to achieve common understanding of all demands and possible solutions, before the project is actually organized and the contract is made. The contract and procurement are based on outsourcing rules; however, the relationship between parties remains based on partnering rules (Table 1).

Table 1: Outsourcing versus partnering

Outsourcing	**Partnering**
Unequal	Equal
One party pays, one delivers	Mutual cooperation
‘Closed book’	‘Open book’
Working on different levels	Working on same level
Different interests	Joint interests
Transaction costs	No transaction costs

In order to build up the partnering relationship, both demanding and supplying parties join in separate partnering arrangements first in order to make an optimal business case on the demand side (e.g. value–revenues–price), as well as on the supply side (value–price–costs). Those business cases are the basis for the integrated business case for the project (value–revenues–price–costs), and an envisaged optimal benefit for the project as a whole (value–costs) (Figure 6).

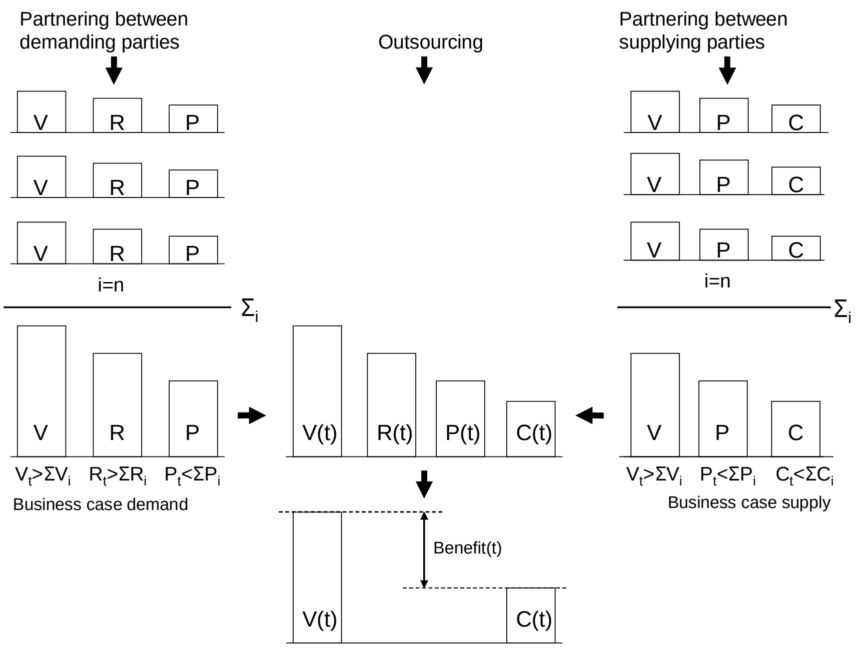


Figure 6: Integrated partnering and outsourcing approach

After the partnering phase, the project organization and contract should be arranged. This process contains three steps (Figure 7). The first step is the determination of the initial area of interest based on the previously established integrated business case. The second step is the selection of the producer based on the best value–price offer. For instance, in this case, producer 2 has the best value–price offer, i.e. the largest angle alpha. So he is the winner of the competition. Step three is to settle an agreement based on the relation between value and price in the area of the producer's offer, i.e. the initial design, and thus the initial value and initial price. The contract area around this point is the 'dynamic control space', in order to be able to change and improve the built object during the contract period when changes occur, e.g. changing regulations, demands from new users and availability of new technology.

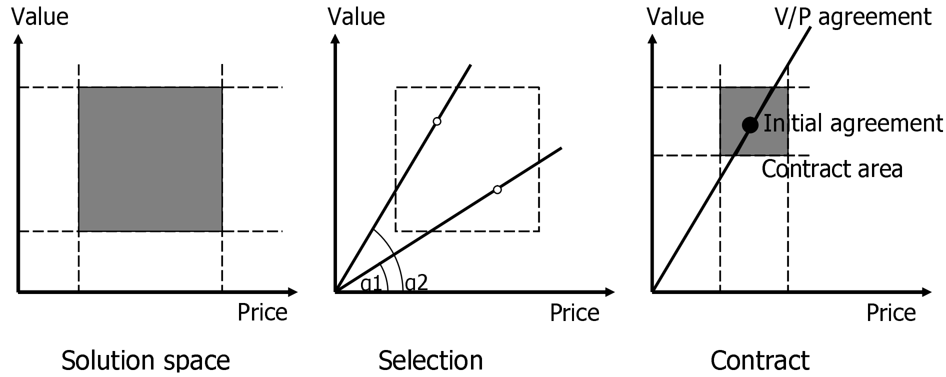


Figure 7: Enabling dynamic control

Next the legal issues are arranged in a contract including responsibilities, liabilities, obligations and risks. For dynamic control it is necessary to know what value against what costs is delivered, but leave open the way how this is achieved. In the present situation however, contractors should comply with drawings and specifications which have been made by the owner and his advisors for a fixed price. In an LBC situation, the big change for the industry is reversing the supply chain that is capable of delivering buildings proactively as if they were consumer goods, that are totally pre-designed and pre-developed, and still flexible enough to be customized to clients' wishes.

EXAMPLE: APPLYING LBC TO A HEALTHCARE FACILITY

In 2006 LBC has been applied to the redevelopment of an existing hospital which was built before in 1983. Owing to changing policy by the national and local government, changing finances of healthcare and increased commercial possibilities in the healthcare sector, the management of the hospital decided to rebuild the hospital and change it into a healthcare centre with multiple services added to it. Application of LBC and its benefits have been studied for this particular case, particularly because healthcare policies are bound to be changing considerably during the coming years. This calls for flexibility of the building and the services in and around the new healthcare centre, and the contractual setting too. Besides, healthcare demand and technology change fast. LBC has been particularly beneficial because client requirements and wishes were captured only in a minimum brief. In this particular case, a traditional briefing process would have taken too much time. The LBC consortium was invited to develop an integrated solution for a new hospital, including all services and technology, and offering solutions to keep the building flexible. In order to increase the commercial possibilities and to ensure sufficient resources for the project, the main solution was found in physically disconnecting core facilities of the total centre from additional services, and reconnecting parts of them flexibly to the hospital. This enables the hospital to flexibly make use of the additional services, and enables it to deliver services to others at the same time too, which increases financial benefits (Figure 8).

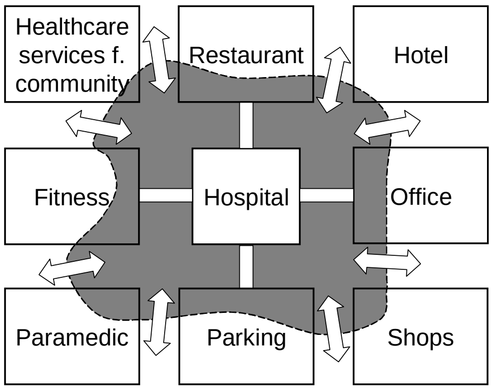


Figure 8: Schematic layout of the flexible healthcare centre

The schedule for this project is rather tight. In the first half of 2007, the brief will be developed further. By the summer of 2007 the tender will be issued, in order to start construction by the end of 2007 or beginning of 2008. The entire project should be delivered in 2010. This requires a fast process, particularly at the start, to ensure the parties go ahead with their parts of the project, and be sure everyone understands the project, and feels comfortable with it.

CONCLUSIONS

The idea of LBC represents a new and comprehensive approach to demand and delivery of built services, based on a dynamic approach to the construction process and the life cycle. The main advantage of the dynamic approach is that an agreement between client and supplier/provider, focusing on measuring the value against price under fast changing circumstances, gives both parties opportunities. The client can easily adapt his facility to new demands, changing regulations, changing circumstances, new education systems, etc. The supplier is able to introduce new technologies, new materials, new concepts, etc. during the contractual period and will be awarded in a corresponding way. However, the client will always decide about new solutions proposed by the supplier/contractor, and these must comply with the performance contract, and always lead to more value than costs. In addition, the decision making is easier and more suitable compared to the current practice in which scope and price are mostly fixed at the start against high transaction costs. By contrast, LBC starts open and ends with a target price within the budget, by means of an open process where client and contractor are equal partners, interacting based on clear agreed-upon rules about the measurement of value and costs, and the establishment of a corresponding price as a result. Such an approach implies a reduced role for the client compared to traditional construction practice, where demand is leading supply. Instead, LBC is based on the idea that supply is leading demand, in a sense that suppliers are able to respond adequately to demands on high aggregation levels, and offering integrated solutions, i.e. a built facility including the services that will keep it 'fit for purpose' during the life cycle, under changing circumstances. The case of the healthcare centre demonstrates that LBC can be beneficial, particularly for healthcare facilities because of the dynamic character of healthcare demands and its context (interest of society, regulations, technology). LBC has offered solutions to cope with the changes and accommodate these in the built facility.

REFERENCES

Abrahams, K and Farrell, P (2003) An investigation into the influence of design and build procurement methods on client value for money. *In*: D Proverbs (Ed.) *Proceedings COBRA*, 1–2 September 2003, School of Engineering and the Built Environment, University of Wolverhampton, 24–34.

Austin, S A and Thomson, D S (1999) Integral value engineering in design. *In*: *Proceedings COBRA*.

Boukendour, S and Bah, R (2001) The guaranteed maximum price contract as call option. *Construction Management and Economics*, **19**, 563–67.

Cain, T C (2003) *Building down barriers: a guide to construction best practice*. London: Taylor & Francis.

De Ridder, H and Vrijhoef, R (2003) The concept of life cycle benefit of buildings: developing a framework for life cycle value management. *In*: *Proceedings CIB W055+065+107 Joint Conference Knowledge Construction*, 22–24 October 2003, Singapore, Vol. 1, 654–64.

Hatush, Z and Skitmore, M (1997) Criteria for contractor selection. *Construction Management and Economics*, **15**, 19–38.

Kelly, J and Male, S (2001) A value management approach to aligning the team to the client's value system. *In*: *Proceedings COBRA*.

Kumaraswamy, M M and Dissanayaka, S M (1998) Linking procurement systems to project priorities. *Building Research & Information*, **26**(4), 223–38.

Luu, D T, Ng, S T and Chen, S E (2003) Parameters governing the selection of procurement system: an empirical survey. *Engineering, Construction and Architectural Management*, **10**(3), 209–18.

Parmar, D, Kashiwagi, D and Egbu, C (2004) Comparison of risk minimization ability of traditional low-bid procurement system and performance information procurement system (PIPS) in construction industry in the USA. *In*: *Proceedings COBRA*, 7–8 September 2004, Leeds.

Thomson, D S, Austin, S A, Mills, G R and Devine-Wright, H (2003) Addressing the subjective view of value delivery. *In*: D Proverbs (Ed.) *Proceedings COBRA*, 1–2 September 2003, School of Engineering and the Built Environment, University of Wolverhampton, 197–213.

Wong, C H, Holt, G D and Cooper, P A (2000) Lowest price or value? Investigation of UK construction clients' tender selection process. *Construction Management and Economics*, **18**, 767–74.

Xu, T and Tiong, R L K (2001) Risk assessment on contractors' pricing strategies. *Construction Management and Economics*, **19**, 77–84.

IMMIGRATION AND THE CONSTRUCTION INDUSTRY: EFFECTS OF IMMIGRANT HIRING PRACTICES AND PENDING IMMIGRATION REFORM LEGISLATION ON CONSTRUCTION INDUSTRY ECONOMICS IN THE UNITED STATES

Sabrina K. Golden[1] and Mirosław J. Skibniewski

Project Management Program, Department of Civil and Environmental Engineering, University of Maryland, College Park, MD 20742-3021, USA

Current estimates indicate an illegal immigrant population of over 11 million residing in the United States; an estimated 19% of this total works in the construction industry. There are several draft bills currently making their way through the US federal legislative process. All of them tighten immigration rules and enforcement, which will ultimately affect the available immigrant workforce. Enforcement of current law will no doubt have a measurable impact on the availability of illegal immigrant workers. Amnesty or some version of a “guest-worker” program would also have a significant impact on the immigrant workforce. Regardless of the scope and breadth of immigration reform, there will be a considerable impact on labour resources for the construction industry. The research will analyse the current hiring practices of immigrants within the construction industry and predict the effects of impending immigration reform on industry economics. Initial predictions of the direction of immigration reform indicate that labour shortages are unlikely; however, increased labour costs are likely due to a prevailing wage provision in the proposed law. Increased costs of around 1% are predicted for projects in the DC metro region.

Keywords: Immigration, labour, project costs.

INTRODUCTION

Current estimates indicate an illegal immigrant population of over 11 million residing in the United States. Almost 40% of this total has been in the US less than five years. An estimated 19% work in the construction industry, which comprises approximately 14% of all construction workforces. Detailed analysis of the Current Population Survey (CPS) conducted by the US Census Bureau reveals that illegal immigrants make up about one-third of the insulation workers, roofers, and drywall installers, and one-quarter of all construction labourers, masons, painters, cement and concrete workers, and carpet and tile installers. This is a significant portion of construction labour resources.

Immigrants, legal and illegal, have migrated to the US in droves over the last five years. As a matter of fact, from 2000–2005, almost 8 million immigrants settled here; it is the highest five-year period of immigration in the nation’s history. Most of the immigrants lack higher education attainment. Almost one-third of all immigrants over 18 and in the labour force have not graduated from high school. For those arriving in

[1] sabrinagolden@gmail.com

the United States since 2000, the estimate is over 34% (Passel 2006). For these poorly educated immigrants, mostly men, willing to work long hours for mediocre pay, the construction industry is an ideal place to find employment. Likewise, the construction industry is in position to receive, employ, and train this abundant work force.

The construction industry, according to the US Department of Labour, Bureau of Labour Statistics, employs over 6 million people, accounting for nearly 5% of the entire US labour force. The value of construction in the US topped $1 trillion in 2004, amounting to 5% of the gross domestic product (Bureau of Economic Analysis, 2007). Additionally, the construction market can be entered with little capital investment, enticing a large group of competitors into the field. As a result, profit margins for construction projects are typically rather small, 5 to 10% or less, with substantial risk for loss.

Between this abundant, low-skilled, highly motivated work force and this enormous, hyper-competitive industry a synergy has developed. This synergy buttressed the industry during the construction boom and labour shortages experienced in the first half of this decade, but promises significant turmoil within the industry given pending immigration reform by the US Congress.

There are several draft bills currently under consideration, which are at various stages in the legislative process. A commonality among the proposals is that they would all tighten immigration rules and enforcement, which will ultimately affect the available immigrant workforce. Research indicates that only about half of all illegal immigrants are paid within the confines of current law. Another 3 million or so have illegally acquired documents authorizing them to work. Estimates also indicate that about a third of all foreign-born workers are illegal immigrants. Enforcement of current law will no doubt have a significant impact on the availability of illegal immigrant workers. Amnesty or some version of a “guest-worker” program will also have a significant impact on the immigrant workforce supply. No matter the scope and breadth of immigration reform, there will be a significant impact on labour resources for the construction industry.

The study’s aim is to analyse the current hiring practices of immigrants within the construction industry and predict the effects of impending immigration reform on industry economics. There are four main objectives:

1. To analyse, by discipline, the current makeup of construction industry workforce, native-born vs. immigrant, and legal vs. illegal immigrant.
2. To assess the pay differential between immigrant workforces (legal and illegal) and native-born workers.
3. To examine the effects of immigration reform policy on the makeup of the construction industry workforce.
4. To predict possible effects on industry economics, including demand, labour costs, project costs and profits.

LEGISLATION

Currently, there are two versions of immigration reform legislation: one bill proposed and passed in the US House of Representatives and one bill proposed and passed in the US Senate. Few issues are as politically charged and garner such widely diverse, intense opinions in the country as immigration. There are two basic philosophies on immigration reform that dominate the scene in the United States: amnesty and enforcement. Following this pattern, the House and the Senate have proposed their own version of immigration reform, one favouring enforcement and the other tending toward amnesty. In effect, there are two bills concurrently making their way through the convoluted legislation process. The first bill introduced in the House of Representatives on December 6, 2005; HR 4437, is titled The Border Protection, Anti-terrorism, and Illegal Immigration Control Act of 2005. Technically, once passed by either House of Congress, a bill becomes an 'act,' but not yet law. The bill passed the House on December 16, 2005, with amendments. It was forwarded to the Senate on 17 December 2005 and the Senate referred the bill to its Judiciary Committee on 27 January 2006. The major provisions of the House bill of particular interest to the construction industry include:

- Requirement for construction of 700 miles of fencing along the border with Mexico in conjunction with deployment of surveillance technology in order to detect and prevent illegal border crossings. This fence is estimated to cost almost $4 million per mile. The cost of 700 miles of fence would amount to almost $3 billion. This indicates a tremendous opportunity for construction companies working in the border area.
- Mandating the use of the Employment Eligibility Verification System by employers. The Department of Homeland Security (DHS) is directed to establish and administer an employment eligibility status database through which an employer can verify the eligibility for employment of potential employees. This system is to be administered in consultation with the Commissioner of Social Security. The system is to be phased in over several years for previously hired individuals. There is also a provision that establishes a responsibility of DHS to investigate possible fraudulent use of Social Security numbers when identical numbers are submitted by multiple employers. Over 20 years ago, the Immigration Reform and Control Act of 1986 made it unlawful for employers to hire illegal aliens and required employers to verify eligibility by a review of an employees documents. Prevalent document fraud has made a mockery of this law. It is estimated that almost two-thirds of immigrant documentation in use today is fraudulent. The Illegal Immigration Reform and Immigrant Responsibility Act of 1996 established three pilot programs of this Employment Eligibility Verification System, whereby Social Security numbers and alien identification numbers of new hires are checked against Social Security Administration and DHS records in order to verify the validity of an employee's documents. Under The Border Protection, Anti-terrorism, and Illegal Immigration Control Act of 2005, this pilot program would be extended and immediately viable for all new hires. Employers would be required to check the eligibility status of all new hires within two years of enactment. On a voluntary basis, employers could check the eligibility of previously hired employees two years following enactment. By three years following enactment, all employers of immigrants working for federal, state, and local governments or in government buildings, on military bases, nuclear energy sites, weapons sites, airports, and other critical infrastructure sites must have verified the eligibility of employees through this system. Six years following enactment, all employers of all immigrants must have completed this verification. This requirement applies to day labour sites

and hiring halls as well. If the estimates are accurate, this requirement by itself could reduce the immigrant workforce by two-thirds over six years.

- Prohibiting grants to state and local governments that harbour illegal aliens through a sanctuary policy. This requires the federal government to take custody of illegal immigrants apprehended by local officials. Sanctuary policies are usually adopted by local governments, i.e. cities or counties. No state, yet, has broadly adopted a sanctuary policy. The policies basically direct local officials not to notify the federal government of illegal immigrants living in their cities. Since immigration is a federal concern, the federal government has jurisdiction. Some policies also eliminate the distinction between illegal and legal immigrants, which allows illegal immigrants to benefit from state services. This provision in the House bill will, in the simplest of terms, make it harder for illegal aliens to live and prosper in the United States. Sanctuaries allow illegal immigrants to live without fear of being caught and deported. With the requirement of local officials to notify the federal government of their knowledge of the presence of illegal immigrants in their localities, this freedom of existence is diminished. This would of course extend to health and human services officials as well as law enforcement officials. So, not only are criminals affected, those seeking assistance or medical treatment will be scrutinized as well. The House bill also makes it illegal to give aid to illegal immigrants, prohibiting charities from giving aid to illegal immigrants without notification to the federal government of their presence. This is another provision discouraging the presence of illegal immigrants.
- Increase in penalties for production and use of fraudulent documents and establishment of a Fraudulent Documents Center within DHS to better track the sources of fraudulent documents. This requirement would also reduce the ability of illegal immigrants to procure documents for employment, thereby reducing the number of illegal immigrants in the workforce.
- Increase in penalties for employing undocumented workers to $7,500 for first offence, $15,000 for second offences, and $40,000 for subsequent offences. In essence, the House bill makes it harder for employers to plead ignorance for hiring illegal immigrants and makes it fiscally prohibitive to get caught doing so.

One of the more politically volatile aspects of the bill is its exclusion of any type of guest worker program. The House bill focuses primarily on enforcement and discouraging illegal immigration. The enactment of this bill would certainly reduce the immigrant workforces available within the construction industry, creating labour shortages in certain disciplines. There is no relief available in this bill for such shortages.

The second bill, introduced in the Senate on 7 April 2006; S 2611, is titled Comprehensive Immigration Reform Act. The bill passed the Senate on May 25, 2006, with amendments. The House bill, The Border Protection, Anti-terrorism, and Illegal Immigration Control Act of 2005 mentioned earlier has been stalled in the Senate Judiciary Committee. Rather than annihilate the House bill, the Senate chose to establish its version of immigration reform and proposed this alternative bill. The major provisions of the Senate bill of particular interest to the construction industry include:

- Requirement for reinforcement of several miles of fencing along the Mexico border and the construction of 370 miles of additional fencing. At an estimate of $4 million per mile, the total cost would amount to almost $1.5 billion of construction.
- Mandating an expanded use of the employment verification system. The system must be in use by all employers for new hires 18 months after the necessary appropriations are made to fund the system, an estimated $400 million. There is no mention of employment verification for existing employees.

Overall, enforcement is not the essence of the Senate bill. The two key provisions in the Senate bill that would drastically impact the construction industry are amnesty for illegal immigrants and the guest worker visa program.

- Amnesty: illegal immigrants present in the United States for more than five years could apply for citizenship. A penalty and back taxes would apply. Illegal immigrants present in the US for 2–5 years would be allowed to remain in the US without fear of deportation and apply for citizenship in 3 years at one of 16 ports of entry. Illegal immigrants present for less than two years would be required to return to their original nations. Amnesty, therefore, would be available to approximately 85% of illegal immigrants. This would significantly reduce the labour shortages experienced in the construction industry.
- Guest Worker Program: the Senate bill establishes the H-2C visa or “blue card.” Companies would be allowed to recruit foreign workers for positions where there are a shortage of U.S. workers available. The employer will be allowed to petition the Department of Labour (DOL) for permission to hire foreign workers after they have shown reasonable effort to recruit US workers. All foreign workers under this program shall be paid prevailing wages. Workers would be allowed to work under this program for 3 years with one 3-year extension. After returning to their home countries for one year, they could reapply. This provision alleviates the labour shortages experienced in some construction disciplines, but makes the cost of recruiting and hiring foreign workers prohibitive.

The Senate bill takes a much softer stance on enforcement and allows provisions for amnesty and guest workers, which would alleviate the strain on current labour resources within the construction industry. However, the guest worker program could prove cost prohibitive.

CURRENT ESTIMATES

Among illegal Hispanic immigrants in the Washington DC metro region, one in three is employed by the construction industry. According to information provided by the Center for Immigration Studies, the construction industry employs more illegal immigrants than any other industry in the US Immigration and illegal immigration, in particular, are hugely important issues within the construction industry.

Analysis of the Current Population Survey (CPS) for 2005 reveals an illegal immigrant population between 11.5 and 12 million. Of those, 7.2 million are employed in the US labour force, with 1.4 million in the construction industry, which comprises 14% of the entire construction workforce. Since guest worker provisions and legalization paths being discussed in Congress differentiate between long-term illegal immigrants (those that have resided in the US more than five years) and short-term illegal immigrants (those that have resided in the US less than five years), it is helpful to break these numbers down accordingly. Again, from an analysis of the March 2005 CPS, 4.4 million illegal immigrants arrived in the US between 2000 and 2005. Another 2.9 million arrived between 1995 and 1999, and approximately 4 million before 1994. By these estimates, the short-term illegal immigrants make up over 35% of the total illegal immigrant population. Of those, approximately 550,000 have found employment within the construction industry (Pew Hispanic Center, 5 &13 April 2006).

Table 1: Illegal immigrant share of specific occupations, March 2005 (in thousands)

Detailed occupation	Total Workers	Illegal Immigrant Workers	
		Number	Share
Total, Civilian Labour Force (with an occupation)	148,615	7,255	4.9%
Insulation workers	56	20	36%
Roofers	325	93	29%
Drywall installers, ceiling tile installers, and tapers	285	79	28%
Construction helpers	145	40	28%
Construction labourers	1,614	400	25%
Brick masons, block masons, and stone masons	198	49	25%
Painters	768	167	22%
Cement masons, concrete finishers and terrazzo workers	141	29	21%
Carpet, floor and tile installers and finishers	330	66	20%

Source: Passel (2006)

Overall, almost 14% of the construction industry workforces are comprised of illegal immigrants. This trend in hiring practices will have a significant impact as the industry braces for immigration reform.

THE NEW FACE OF THE WORKFORCE

Based on this information, how will immigration reform change the make-up of the US construction workforce? Following, we consider each element of reform and anticipate its impact on the labour force.

The Employment Verification System will be mandated for new hires and existing employees. New hires will require immediate verification and existing employee verification will be phased in over several years.

This aspect in itself will have huge impact. There have been several studies that conclude approximately half of illegal immigrants have provided valid Social Security Numbers (SSN) in order to obtain employment. There are two ways that an illegal immigrant can obtain a valid SSN: (1) the SSN was stolen or otherwise illegally obtained from someone who is authorized to work in the US or (2) the SSN was issued by the Social Security Administration. There are some illegal immigrants that are authorized to work in the US, for instance, asylum seekers whose cases have not yet been adjudicated. Thus, it is not clear how many illegal immigrants have illegally acquired SSNs, but the number is likely to be significant (Camarota 2004).

The mandated use of the employment verification system will make it more difficult for illegal immigrants to deceive employers who are attempting to comply with the law. The immediate deployment of the system for new hires will deter the influx of illegal immigrants directly. The phased deployment of the system for existing employees will likely encourage the departure of illegal immigrants before they are apprehended.

Document fraud will be more strictly enforced in conjunction with the Employment Verification System. Harsher penalties will be levied against those found to be involved.
This is likely to deter illegal immigrants from improperly obtaining worker authorization documents and decrease the number of illegal immigrants in the workforce.

Higher penalties will be enforced for unlawful employment of illegal immigrants, probably along the lines of the House bill.
This appears positive, but without enforcement, it means little. Penalties for hiring illegal immigrants already exist in the law. Enforcement will be the key for this component of the bill to have any effect.

Amnesty will be allowed for those illegal immigrants living in the US for longer than five years.
This element will have far reaching effects: 60%of illegal immigrants have resided in the US. more than 5 years. Thus, they would be eligible for legal residency under this provision. Approximately 7 million illegal immigrants would be eligible for Legal Permanent Resident (LPR) status under this provision. In addition, another 3 million family members living abroad, spouses and minor children, will be eligible for LPR status.

The H-2C visa program for guest workers will be included with the prevailing wage provision intact to discourage use by employers and protect US workers.
The guest worker program will allow another 19% of illegal immigrants currently residing in the US to remain. Illegal immigrants that have lived in the US for 2–5 years are eligible for Deferred Mandatory Departure (DMD) for up to three years. Within those three years, they will be allowed to return to a port of entry and apply for the H-2C visa program. The H-2C visa program has a cap of 200,000 admissions annually; however, DMD applicants are exempt from this cap. Through DMD and H-2C visa program, another 2.2 million illegal immigrants would immediately be eligible for legitimate worker status, but at a price (Camarota June 2006).

Employers of guest workers will be required to pay prevailing wages to these employees. There is still some discussion of whether to use the wage determinations from the Department of Labour as required by the Davis-Bacon Act of 1931 or wage data garnered from information and data collected by the Bureau of Labor Statistics (BLS). Either way, the cost of immigrant labour will increase.

In summary, immigration reform will deter hiring practices of illegal immigrants, but will allow the vast majority of illegal immigrants a path to legal status. Thus, this does not represent a true zero-sum game. Nearly 80% of illegal immigrants are likely to be granted some form of amnesty and be allowed to continue to work in the US. However, employers will see a rise in the cost of immigrant labour.

LABOUR COST FOR CONSTRUCTION PROJECTS

Labour costs account for over half the direct costs of construction projects in the US. Table 2 is a comparison of hourly wage estimates for immigrant-intensive disciplines taken from Davis Bacon Wage Determination and BLS data. These data will be used in determining prevailing wage rates paid to newly eligible immigrants who qualify for the guest worker visa program. The BLS data is the median for wages paid for the detailed occupation category listed. The Davis Bacon wage listed comes from the wage determination from the DOL. There is considerable controversy within the industry over the validity of the prevailing wage determination made by the DOL. DOL collects data from employers in order to determine the prevailing wage. Many feel that labour unions, who offer their wage data more freely than private industry, skew the numbers towards union rates and, therefore, the prevailing wage determination is not an accurate reflection of prevailing wages in the region. BLS data comes from annual surveys of employees. Currently, "prevailing wage" language means Davis Bacon wages as determined by DOL wage determinations. Lobbyists are working hard to change this generalization and hope to replace DOL wage determinations with BLS median wage data. However, for the purposes of this research, we consider prevailing wages to be predominantly union-scale wages based on provisions of the Davis-Bacon Act and BLS median wages to be the average wage for that particular construction labour specialty.

Table 2: Hourly wage determinations for Montgomery County, Maryland

Construction Labour Specialty	**Davis-Bacon**	**BLS**
Insulation workers	$30.58	$20.11
Roofers	$29.56	$16.25
Drywall installers, ceiling tile installers, and tapers	$17.44	$15.84
Construction helpers	$11.48	$11.65
Construction laborers	$11.74	$12.69
Brick masons, block masons, and stone masons	$22.69	$19.88
Painters	$29.37	$16.80
Cement masons, concrete finishers, and terrazzo workers	$17.44	$16.15
Carpet, floor, and tile installers and finishers	$20.76	$18.59

THE IMPACT ON PROJECT COSTS

Scarcity of labour is not a likely result of the pending immigration reform. The Electronic Verification System will allow existing illegal immigrant employees to remain employed without detection for up to six years. Eighty percent of illegal immigrants will be allowed some form of amnesty, either through access to LPR status immediately available to those that have resided in the US over five years or DMD status for those that have lived in the US for 2–5 years. DMD immigrants will be eligible to apply for guest worker status with little effort, so the industry is not likely to suffer further labour shortages as a result of immigration reform.

However, the attractiveness of immigrant labour will subside slightly due to the prevailing wage requirement included in the reform bill. Currently, immigrants earn approximately 75% of native-born wages, (Kochhar 2005). This difference is not due solely to the foreign-born factor, or to legal or illegal immigration status. The primary driver of depressed wages is the lack of high school and higher education among the construction workers. Over one-third of all immigrants lack high school education. Education is the best predictor of economic success for individuals, regardless of immigration status, (Camarota 2004).

Additionally, only about 55% of illegal immigrants are paid "on the books", i.e. payroll taxes are deducted and matched by the employer. Payroll taxes include income, Social Security, Medicare, and Workman's Compensation (Camarota 2004). Depending on the discipline, this could account for half of the cost of the employee to the employer.

To quantify the effect, the following analysis was conducted on cost data for five commercial construction projects. The projects were all from the DC metro area, so prevailing wage determinations were collected from DC, Northern Virginia, and Maryland. The projects were all commercial construction: three high-rise office buildings, one high-rise condominium structure, and one institutional structure. Labour burden was estimated to be 33.6%: 17% worker's compensation insurance, 16.6% unemployment costs for federal and state and Social Security taxes. These are national averages for labour burden taken from BLS.

Table 3 shows an analysis of cost data in five construction labour specialties saturated with immigrant labour: concrete, masonry, drywall, painting, and flooring. Terrazzo installation was included for the projects for which there was data. Overall, the impact appears less than 1% of total project cost, but with profit margins on the order of 5–10%, 1% would certainly become a noticeable impact.

Table 3: Estimated increase in project costs

	% Illegal Immigrant Workers	% DMD	Median Wage	Prevailing Wage	% Payroll Taxes	% Increase in Total Labour Cost	% Increase in Total Project Costs
Project 1: Virginia							
Concrete	21%	4%	$14.18	$30.91	9%	1.66%	
Masonry	25%	5%	$19.57	$22.69	11%	1.13%	
Drywall	28%	5%	$15.24	$30.91	13%	2.72%	
Terrazzo	21%	4%	$14.13	$30.91	9%	1.66%	
Painting	22%	4%	$14.10	$29.37	10%	1.73%	
Flooring	20%	4%	$14.68	$20.76	9%	0.92%	
Project Totals						1.77%	0.27%
Project 2: Maryland							
Concrete	21%	4%	$16.15	$30.91	9%	1.43%	
Masonry	25%	5%	$19.88	$22.69	11%	1.11%	
Drywall	28%	5%	$15.84	$30.91	13%	2.60%	
Terrazzo	21%	4%	$16.15	$30.91	9%	1.43%	
Painting	22%	4%	$16.80	$29.37	10%	1.42%	
Flooring	20%	4%	$18.59	$20.76	9%	0.69%	
Roofing	29%	6%	$16.25	$29.56	13%	2.58%	
Project Totals						1.57%	0.52%
Project 3: Virginia							
Concrete	21%	4%	$14.18	$30.91	9%	1.66%	
Masonry	25%	5%	$19.57	$22.69	11%	1.13%	
Drywall	28%	5%	$15.24	$30.91	13%	2.72%	
Painting	22%	4%	$14.10	$29.37	10%	1.73%	

Flooring	20%	4%	$14.68	$20.76	9%	0.92%	
Roofing	29%	6%	$16.25	$29.56	13%	2.58%	
Project Totals						1.85%	0.89%
Project 4: Washington DC							
Concrete	21%	4%	$19.85	$30.91	9%	1.13%	
Masonry	25%	5%	$19.88	$17.75	11%	0.82%	
Drywall	28%	5%	$15.84	$29.12	13%	2.43%	
Painting	22%	4%	$17.06	$29.37	10%	1.40%	
Flooring	20%	4%	$18.59	$33.10	9%	1.20%	
Roofing	29%	6%	$24.33	$29.56	13%	1.62%	
Project Totals						1.36%	0.52%
Project 5: Virginia							
Concrete	21%	4%	$14.18	$30.91	9%	2.11%	
Masonry	25%	5%	$19.57	$22.69	11%	1.78%	
Drywall	28%	5%	$15.24	$30.91	13%	3.53%	
Painting	22%	4%	$14.10	$29.37	10%	2.23%	
Flooring	20%	4%	$14.68	$20.76	9%	1.33%	
Roofing	29%	6%	$16.25	$29.56	13%	3.45%	
Project Totals						2.28%	0.93%

To reach the above conclusions, the following assumptions were made:

- The estimates of illegal immigrant workers are accurate for these projects. Pew Hispanic Center believes that these estimates for the Washington, DC metro area may be low. Additional research is ongoing to determine better estimates for this region.
- Of those illegal immigrants eligible for DMD, all will apply for guest worker visas. Employers will be required to pay these employees prevailing wages. The inflationary impact of this action on other wages for these projects was omitted. Further research will be necessary to quantify this impact.
- Payroll taxes for 45% of illegal immigrants are not currently being paid. Following immigration reform and the instatement of the Electronic Verification System, employers will experience more difficulty in paying employees "off the books." Therefore, payroll taxes will be paid by employers for these existing employees currently being paid "off the books".
- Labour accounts for 65% of subcontract costs. This is a rule-of-thumb used by estimators, and more detailed estimates should be addressed for affected construction labour specialties.
- All other factors affecting construction economics have been ignored. Immigrant labour supply and immigration reform have been isolated in order to analyse impact. Construction demand has been assumed to be stable and immigrant labour has been assumed to be plentiful. Economic expansion or recession has not been addressed. Additional research is required to include these factors in a more detailed analysis. Inflationary impact as a result of prevailing wage legislation has also been omitted thus far.

CONCLUSIONS

The research in this area continues. Currently, specific trades in the Washington DC metro area are being studied to determine the ratio of workers that will be affected by the pending reform. Increased project labour costs of 1% are estimated thus far, assuming the most likely political scenario related to the passage of the reform measures under consideration. It is predicted that this estimate will rise with more detailed and accurate data regarding worker demographics. Further study will address: (1) specific trades affected most dramatically by anticipated reform; (2) the amplitude of the effect based on the possible extreme scenarios of the reform; and (3) proposed mitigating efforts by the construction industry itself.

REFERENCES

Bureau of Economic Analysis (2007) Gross domestic product by industry accounts, 26 April. Available online: www.bea.gov

Bureau of Labor Statistics (2006) Foreign-born workers: Labor force characteristics in 2005, 14 April. Available online: www.bls.gov

Camarota, S A (2004) The high cost of cheap labor: Illegal immigration and the federal budget. Center for Immigration Studies, August. Available online: www.cis.org

Camarota, S A (2005) Immigrants at mid-decade: A snapshot of America's foreign-born population in 2005. Center for Immigration Studies, December. Available online: www.cis.org

Camarota, S A (2006) Amnesty under Hagel-Martinez: An estimate of how many will legalize if S.2611 becomes law. *Backgrounder*, June. Available online: www.cis.org

House of Representatives, US Congress (2006) Border Protection, Antiterrorism, and Illegal Immigration Control Act of 2005, H. R. 4437, 27 January.

Kochhar, R (2005) Latino Labor Report 2004: More jobs for new immigrants but at lower wages. *Pew Hispanic Center Report*, May. Available online: www.pewhispanic.org

Passel, J S (2005) Unauthorized migrants: Numbers and characteristics. Background briefing prepared for task force on immigration and America's future. *Pew Hispanic Center*, 14 June. Available online: www.pewhispanic.org

Passel, J S (2006) The size and characteristics of the unauthorized migrant population in the US: estimates based on March 2005 Current Population Survey. *Pew Hispanic Center Research Report*, 7 March. Available online: www.pewhispanic.org

Pew Hispanic Center Fact Sheet (2006) Recently arrived migrants and the Congressional debate on immigration, 5 April. Available online: www.pewhispanic.org

Pew Hispanic Center Fact Sheet. (2006) The labor force status of short-term unauthorized workers, 13 April. Available online: www.pewhispanic.org

Senate, US Congress (2006) *Comprehensive Immigration Reform Act of 2006*, S. 2611, 7 April.

THE ROLE OF DEFECTS AND REWORK IN THE DRIVE FOR SUSTAINABLE CONSTRUCTION

James Sommerville[1] and Nigel Craig

School of the Built and Natural Environment, Glasgow Caledonian University, Glasgow, G4 0BA, UK

Various reports have identified the need for a consistent reduction in the level of construction defects. The reality of course is that little has been done to improve the industry's record with regard to the origins and causes of defects, nor their eradication. The research aimed to determine the role actors in a range of defects and the impact of the defects on sustainable construction. Detailed analysis of defects found within the house building sector shows a continuing trend towards acceptance of the inevitability of defects.. Analyses of some 200,000 defects in 3696 new homes shows that whilst there are a number of prime origins, the actual cause of the defects on site can be attributed to a single entity – the humans. Discussion is given to the impact of the defects and the need for management of the causal agent. These initiatives are then contextualized within the drive for sustainable construction. The figures and analyses from this research represent the most accurate statistics on snagging in the UK. What is clear from the research is the failure to grasp a significant opportunity to improve sustainability performance and at the same time bring about a significant increase in customer satisfaction.

Keywords: building defects, customer satisfaction, sustainability, new homes, snagging.

INTRODUCTION

The last decade has witnessed a constant clamour from both clients and government for improvements in the quality of the finished product delivered by the house building sector of the UK construction industry. The UK government's ambitions to improve the quality of new homes have prompted a number of house builders to consider the implementation of quality initiatives such as Total Quality Management (TQM) and ISO 9000 (Sommerville 1994). The use of these quality initiatives is at best questionable and their adoption does not appear to be a guarantee of an improvement in the quality of the finished article (Sommerville *et al*. 2004).

In the house-building arena, the house builder sets the specification requirements (finished product), the customer is perceived as a simply a 'buyer' that purchases the final product with its inherent defects or 'snags'. The importance of snagging is shown by the fact that the last three Housing Forum/MORI customer satisfaction surveys carried out in 2000, 2001 and 2003 and the House Building Federation customer satisfaction survey in 2006 report an increasing number of new home purchasers as being unhappy with the finished quality of their new home, with the recorded levels of satisfaction showing a downward trend.

The volume of research specifically related to snag levels or indeed quality in new-build housing is remarkably scant given the size of the industry. The research that is

[1] jso@gcal.ac.uk

there focuses predominantly on regulatory defects, i.e. contraventions to either building regulations or the warranty providers' standards. Whilst researchers have made some inroads into describing and understanding the phenomenon of defects and rework, the literature available has tended to concentrate upon the major project environment. There is limited literature that incorporates current knowledge of not only snags and snagging but the quality problem within new build housing, more work needs to be done to unite the disparate research areas.

Initial analysis of snag data from 3696 new homes built by 420 UK house builders demonstrates the levels of snags a home buyer could expect to find when purchasing a new home. It is clear that snags are a major problem within the industry and one that requires major attention if Egan's (1998) dream of reducing defects at handover by 20%, year on year is to become reality.

EGAN – NEGATIVE IMAGE AS A DRIVER

As a result of the perceived negativity hovering around the image of the UK housing industry, the government published two significant reports in an attempt to drive up the quality of the final product. The reports themselves (Latham 1994; Egan 1998) were mainly focused upon the commercial sector although they have strayed into the speculative house building sector (Sommerville and McCosh 2006). Egan (1998) argues that quality must be fundamental in the design process and that defects and snagging need to be designed out on the computer before work starts on site. He also proposes that by achieving a reduction of 20% in the number of defects found in handover annually that the goal of zero defects is achievable across construction within five years. In spite of this, he fails to provide any clarity as to how this recommendation was generated, let alone any approach to the attainment of the 20% reduction; further, he fails to provide evidence to suggest that his theory of a five-year time scale in achieving zero defects will be obtainable. It can also be argued that if a timescale and factor of improvement figure had been provided then a benchmark defects figure for the construction industry to use to measure performance should also have been provided. The Modernizing Construction Report (2001) rightly highlights that there is a serious lack of reliable and quantified information that can be used to evaluate the performance of individual projects never mind the industry. Such information is essential for setting reliable targets and estimates for future performance

The reports focus on the need to reduce the number of defects in construction and highlight the increasing importance of after-sales customer care. Sound after-sales customer care is an integral part of overall quality that exceeds customer expectations and provides a real service benefit to the end user. Given the discussion above, it becomes apparent that The Egan Report (1998) may not be directly applicable to the speculative house-building sector of the construction industry.

THE PROBLEM WITH DEFECTS/SNAGGING AND REWORK

The ongoing quality problem within the industry suggests that one of the main drivers of the Egan report (reduction in defects of 20% p.a.) has been ignored and a golden opportunity missed.

Understanding defects and rework in new UK houses strikes at the very heart of the wider construction industry since the contribution to the UK construction industry's output made by the new private-housing segment is significant, as shown in Figure 1.

The data shown in Figure 1 has been drawn from the UK's DTI (2005) statistics on the industry and shows, in relative terms, that the private new-housing segment is the largest of the three segments, which coalesce to make up the new-works section of industry output. Even though this new private-housing segment is the largest element in the composite new-works section, it is often ignored due to its fragmented nature and its myriad of clients – the individual new house buyers.

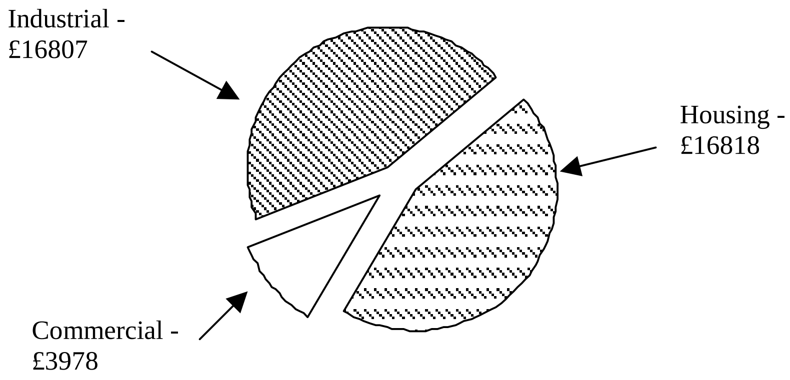


Figure 1: The distribution of UK new works: £ Millions (source: DTI 2005)

With this multiplicity of clients, there is an implicit argument that the house builders will focus on the quality of the product they offer in order that they differentiate themselves from rivals and attract buyers. These house buyers of course have their own set of quality expectations, i.e. requirements, which are often at odds with those of the house builder.

QUALITY EXPECTATIONS OF UK NEW HOUSE BUYERS

The quality drive in the UK new-housing sector arises not only from the buyer, but also from two main industry forces: firstly, the marketing efforts of the individual house-builders, which sees the house-builder trying to convince a fickle buying public that their product is as good as, or superior to, that offered by the rivals and therefore the one to have; and, secondly, the need for the house builder to reach various minima dictated by a range of regulatory bodies such as Building Control or the National House Building Council (NHBC).

Against this drive for pluralistic client satisfaction, we have to balance a multi-billion pound industry within which one of the largest companies sees their core business as being a retailer, rather than a house-builder. Lorentzen (1996) argued for this underlying presumption, that new houses are now consumer products, with his contention that a home could be seen as a consumer product, albeit a very expensive one. Thus we have a multi-billion pound industry, manufacturing and producing very expensive consumer products, but with little research on the end-customer's requirements and scant consumer legislation to protect the buyer (Mills 2000). The Barker Review (2004) reinforces the view that more has to be done to raise the quality standards of a number of the leading house building companies, noting that "the need to improve standards applies right across the industry".

This need to improve quality standards is in part driven by the levels of defects and rework found in new houses and also through various reports (e.g. Ball 1996; Barker 2004), which clearly indicate that all is not well with the products currently being delivered (i.e. the mismatch between Technical and Functional Quality). A number of high-profile instances have shown that the quantity of defects and rework, on relatively small new houses, can be enormous. The case of Langridge (2005) illustrates this point: after the buyer moved in to a one-bedroom house, valued at £500,000, it was found to have 86 defect items requiring rework. Whilst this case appears on the surface to be ‘cut and dried’, it highlights the need to define precisely what the defects are, what the associated rework is and the defects’ root causation.

MEASURING USING KEY PERFORMANCE INDICATORS

Key Performance Indicators (KPIs) are a form of benchmarking that has been adopted in construction allowing performance to be measured and analysed, thus enabling continuous improvement to be developed and implemented. KPI charts rate defects from 1–10 on the y-axis as can be seen in Figure 2. This scoring indicates the level of defects in construction: the higher the rating the lower the number of defects there are. If the contractor or house builder receives a low rating, it indicates that the end product is riddled with defects upon handover. This rating is determined by the client but in the speculative house building sector it will be the home builder who applies the final rating. Constructing Excellence characterize the ratings as follows:

“**Definition**: Condition of the facility with respect to defects at the time of handover, using a 1 to 10 scale where:

10 = Defect-free.

8 = Some defects with no significant impact on the client.

5/6 = Some defects with some impact on the client.

3 = Major defects with major impact on the client.

1 = Totally defective. (Constructing Excellence 2006)

An organization can then use the KPI charts to gauge how their own performance compares to their competitors. This is carried out by rating a building at handover using the above rating system and plotting the result onto the graph. By marking the rating with a horizontal line, the performance is identified at the point where this line intercepts the curved line and a percentage identified. An example could be where a defect performance rating of 9 is achieved. This score of 9 is plotted horizontally (see Figure 2) and this would provide an organization with a benchmark score of 85%. A rating of 85% would indicate that 85% of companies are achieving equal or lower than this and 15% are achieving higher. The above scoring format for rating performance is adequate; however, the rating process itself has inherent issues in that it is highly subjective in nature. Therefore, for the data that is produced by this process to be accurate, a considerable responsibility lies with the home builder to be completely truthful when rating their products (new homes) and they are more likely to rate their products higher than the end customer would. For example, the terms major and minor impact are not defined and the home owner may interpret these terms in a different way. The reality is that a completely different set of results would be produced if it was the home owner who was rating the new home as opposed to the home builder. This demonstrates that there is a degree of one sidedness embedded within the current process and is a process that does not take into account customer satisfaction information obtained from the most important member of the house buying process “the customer”.

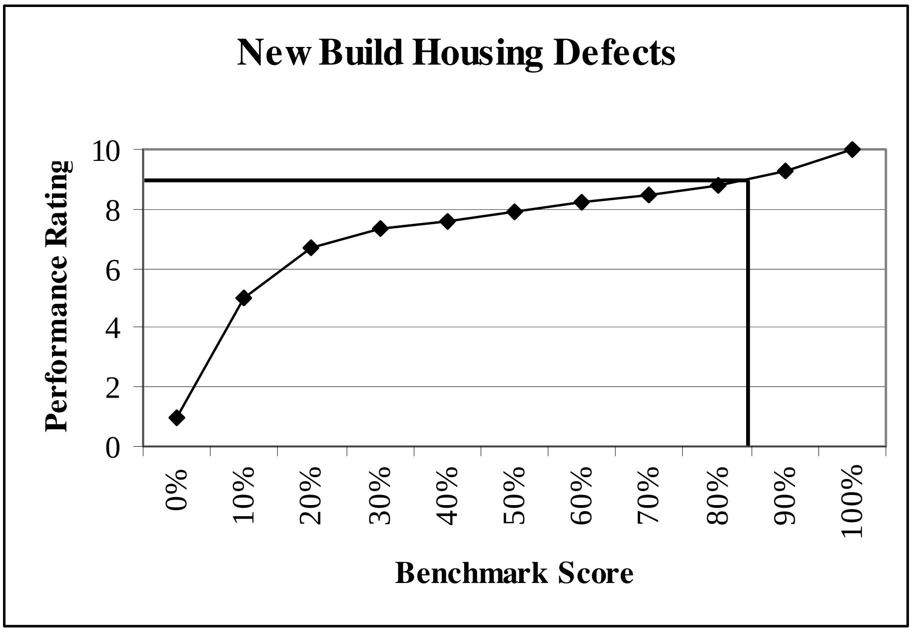


Figure 2: KPI graph indicating the benchmark score for defects within new homes in the UK (adapted from Constructing Excellence, 2006)

MEASURING INDUSTRY PERFORMANCE – NATIONAL CUSTOMER SATISFACTION SURVEYS

The UK Housing Industry performance has also been measured in recent years using national surveys. Surveys carried out by the Housing Forum in 2000, 2001 and 2003 and the House Building Federation in 2006 have focused upon the customer in order to generate results that reflect the customer's opinion of their newly built home. On the face of it, these surveys are sporadic, in that they are not carried out annually; unlike KPI data, which is now produced on a constant basis. However, when these customer surveys are carried out, very similar questions are asked each time. Since the same questions have been utilized in each survey, it is possible to agglomerate the results for the national surveys of 2000, 2001, 2003 and 2006, and from this agglomeration to identify trends from within this enveloping period as displayed in Figure 3.

What is evident from Figure 3 is that the overall levels of quality, finish and condition of the new home display downward trends whilst, at the same time, the amount of home owners reporting snags within their new homes is on the increase (having risen by 12% over the last six years). The apparent misnomer in that the overall quality is falling and yet the buyers are happier would perhaps lie in the improvement in the approach to Functional Quality being implemented by the house builders (Technical Quality being taken for granted). If no action is taken to prevent this trend continuing, it can be assumed that the overall quality of new build homes will continue to decrease. In comparison, however, the new build housing KPIs taken over the last six years show an increase in the number of organizations scoring 8/10 or better from a figure of 50% in 2001 to a figure of almost 78% in 2006. We thus have an industry which indicates that performance levels are increasing with regards to overall satisfaction and reduction in defects levels, but end customers who indicate that the overall quality of their new homes is decreasing whilst snagging levels have risen dramatically. The snagging process or indeed the collection of snagging data has rarely been written or reported upon within the UK construction and housing industry which has resulted in a dearth of literature and data sets available to the authors of this paper. The data sets available for analysis within this research are limited: both in terms of the actual quantity of data available and the access to such data sets from different members of the snagging process chain.

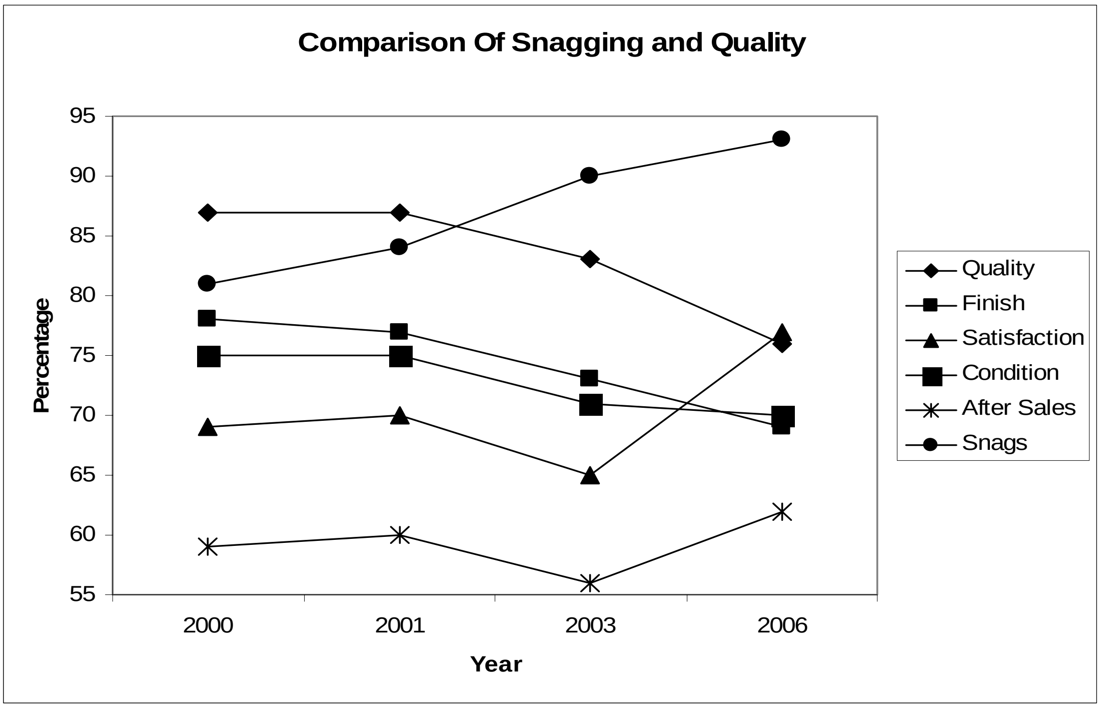


Figure 3: Trends from housing surveys 2001–2006(adapted from Constructing Excellence 2000, 2001, 2003 and HBF 2006)

AIM AND OBJECTIVES OF THE RESEARCH

The research aimed to determine the role actors within a broad spectrum of defects and the impact of the defects on sustainable construction.

Objectives: to determine the level of snags prevalent within new homes in the UK; to discern the link between snags and a sustainable industry; to discuss the industry's utilization of KPIs; and to disseminate the findings form the research.

In order to achieve the stated aim and objectives, a robust methodology is required, the discussion of which follows.

METHODOLOGY

There is an implicit constraint within the methodology that the data used in this research was extracted from a data set provided by the UK's leading independent new home snagging company. The argument would be that this is a biased population. Indeed the contrary may be argued since it is the only detailed independent dataset available and as such, is deemed to be robust until new data sets are made available within the public domain.

A comprehensive snagging report has been produced for each of the 3696 new homes; these reports being generated over a period of 5 years (under the instructions of the home buyer) through 57 inspectors based around the UK. The reports have been formatted and analysed with the resultant dataset containing detailed information on 200,000 snagging items found within the 3696 properties built by some 430 house builders.

Data available for extraction from the inspection reports included a host of detail on: the name of the client, the location of the property, the type of property, the house builder, the independent inspector, date of inspection, number and type of snag and so on. For the sake of clarity in this paper, the list noted above has been truncated. The variables within the datasets were numerically coded for statistical analysis. The names of 'clients', 'inspectors' and 'building companies' are not specified for confidentiality reasons.

After the initial examination of the data, it was clear that for many of the factors, such as builders and inspectors, there were a number of categories with very little data. These categories with low frequencies were then excluded from further analysis. The formatting of the data involved the examination and analysis of over 2m individual data cells. This paper will include analysis on select variables contained in the dataset, which will give an initial picture of the extent of snagging in the UK house building sector of the UK construction industry.

DATA ANALYSIS

All of the new homes inspected on behalf of homeowners, property investors and developers were inspected after the properties had been checked and verified by the appropriate warranty provider and passed over by the developer to the new home owner. Over 90% of properties were checked in the week prior to completion. This is an extremely important aspect as the figures demonstrate a true reflection of the current industry quality standards, rather than just a reflection of all the worst properties in the UK.

There is a considerable range between the highest and lowest number of snags found within a new home. For the first time during this research project a new home (One bedroom flat) has been accredited with having zero snagging items. However, the highest number of snagging items found within a new home has dramatically increased from a figure of 389 to a new level of 452 (six-bedroom house located in the south of England).

The first factor considered during the analysis of the 200,000 snagging items was the average number of snags across the 3696 properties over a five-year period 2002–2006. A decrease in the average number of snagging items found within new homes in 2002–2004 can be seen in Figure 4. The average for 2005 increased by some 19% although the overall performance for 2006 shows a marked increase in overall quality with an average figure found of 46.3.

Considering the average number of snagging items for all house types, further analysis was undertaken to identify the average number of items found within house types of a particular size, in this case by the number of bedrooms. The results of this can be seen in Figure 5. From the analysis of the 3696 new homes, it became clear that as the number of bedrooms in a property increased, so did the number of snagging items associated within each property type, although over time the number of items found within particular house types is slightly decreasing. Although it might be reasonable to expect an increase in the incidence of snags as the bedroom number increases, the full extent of this increase was not expected. The fall in the average number for 1 and 5

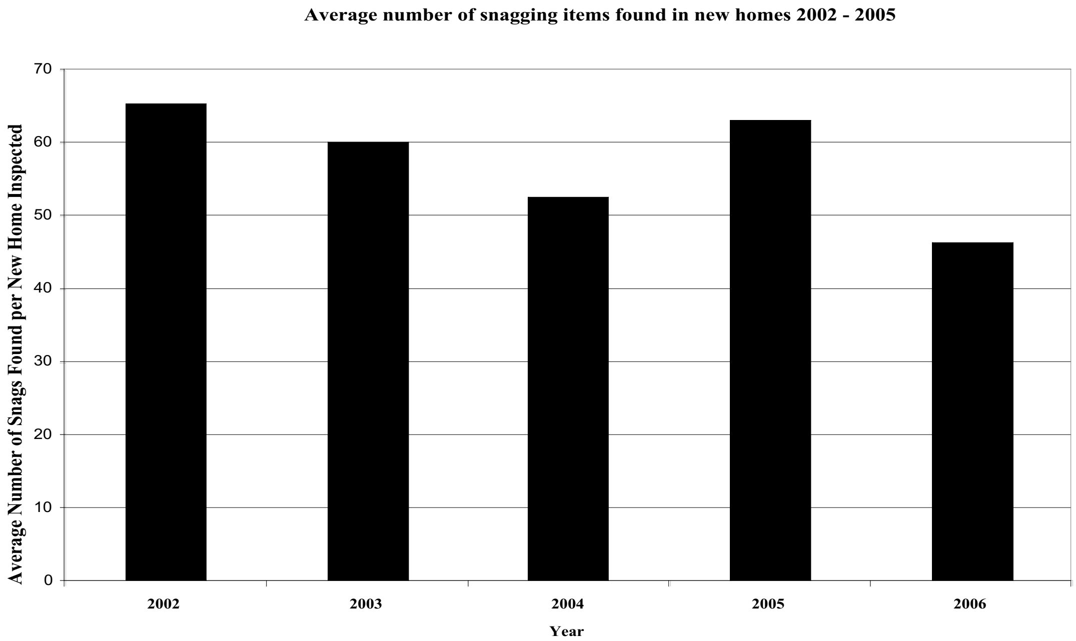


Figure 4: Average number of snagging items per property 2002–2006

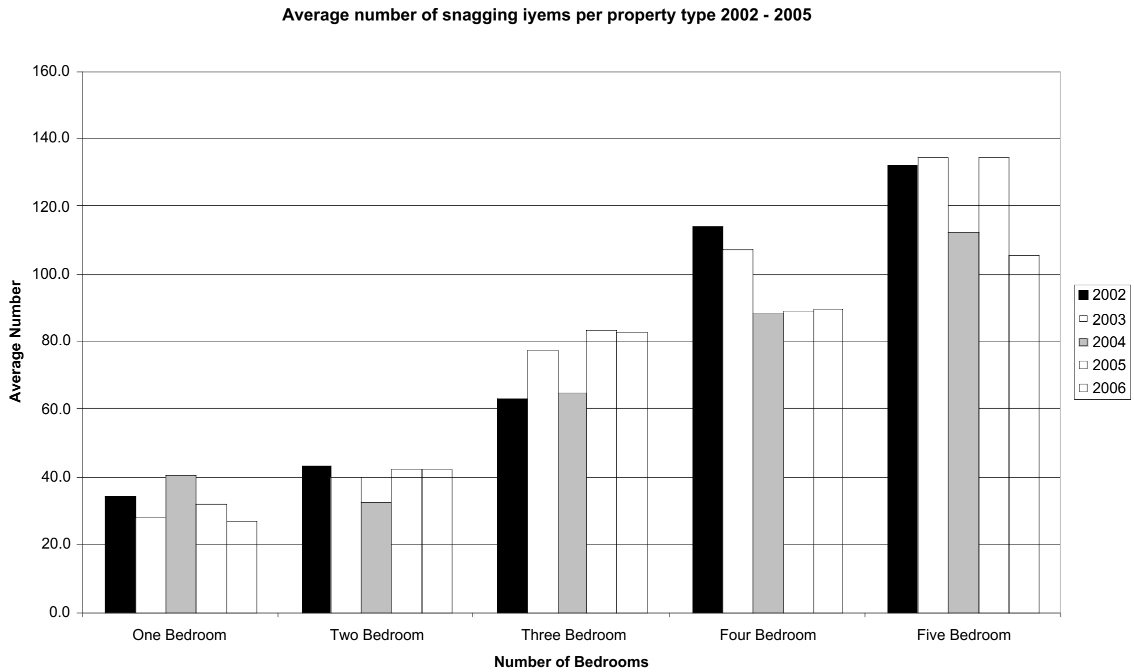


Figure 5: Average number of snagging items per property type 2002–2006

bedroom properties in particular follows the general trend set within the average figure for the whole of 2006. The figures for 2006 are a marked improvement on the overall figures for 2005 although the overall performance levels of the house building industry still have a long way to go in order to achieve Egan's dream of zero defects.

The apparent dichotomy in Figure 3 may arise from significant efforts by a number of the major house builders to improve their Customer Satisfaction activities. These activities are in effect masking the buyers underlying perception of the quality of the product and at the same time embedding the losses to be sustained by the house builder during the construction phases. These losses of course detracting from the industry's sustainability drive.

CONCLUSION

The lack of detailed research in this area prohibits us from discussing these findings directly with prior work/s. However, previous research in associated areas has shown the loss to the industry has a direct impact on its sustainability. Whilst this work is centred on new housing, a full-scale industry wide research effort is required to delve into the issues and arrive at a broadly meaningful set of conclusions.

New homes within the UK are being repeatedly handed over to the end customer with very high levels of snagging items that cause the customer to be dissatisfied with overall quality. The research within this paper has demonstrated that current snagging levels found within new homes in the UK are at a level that must be perceived as damaging to the house-building sector's image and they detract from customer satisfaction. The house-builders of course could be asked to shoulder some of the blame for this lack of quality focus but the responsibility may better sit on the shoulders of the numerous buyers who have accepted products with lower than anticipated quality standards.

Quality initiatives within the industry have been promulgated and implemented under a number of guises and yet the end product – the new home is still sadly lacking in quality. The investigations have also shown to some extent that the dream of zero defects within five years, proposed by Egan, was in reality unachievable and this research has been undertaken nine years after this proposition was made.

The problem of managing performance has also been examined and links have been found which have displayed a total lack of agreement between the parties involved in house building. The KPIs are indicating that 78% of all new house builders (self rating) are achieving performance measures of between 8/10 whilst at the same time overall customer satisfaction within the industry continues to drop at an alarming rate and snagging items reported continue to rise.

Modern house builders and developers ought to feel the effects that new services such as snagging surveys are having on the industry. There may eventually have to be a change with regard to the snagging process, as the process already implemented is not addressing the problem adequately. If the construction industry is able to produce an improved way of monitoring errors, defects and snags when constructing then hopefully this will be implemented and the dream of zero defects, if not realized, then the number of items can be dramatically reduced. This in turn would boost customer satisfaction figures.

Future work will examine in further detail the snagging data already collected from the independent surveys. This data will be mined and analysed in order to determine what snagging items are Functional and what items are Technical which will give an overall view of the types of snagging items currently found within new homes. By determining the Technical and Functional aspects of snagging, it will be possible to identify which items can be avoided and removed from snagging lists at the point of handover. This will not only improve industry performance and sustainability but also result in customers being more satisfied with the overall quality of their new home.

REFERENCES

Ball, M (1996) *Housing and Construction: A troubled relationship*. Bristol: Policy Press.

Barker, K (2004) *Review of Housing Supply-Delivering Stability: Securing our Future Housing Needs*. Norwich: HMSO.

Constructing Excellence (2006) *UK Construction Industry Key Performance Indicators, New Build Housing KPIs*. Constructing Excellence.

DTI (2005) *Housing & Construction Statistics*. Available online: http://www.dti.gov.uk/sectors/construction/ConstructionStatistics/page16429.html

Egan, J (1998) *Rethinking Construction: The report of the Construction Task Force*. London: Department of the Environment, Transport and the Regions.

Home Builders Federation (2006) *New Home Customer Satisfaction National Survey*. Home Builders Federation.

Housing Forum/MORI (2000, 2001 & 2003) *Housing Forum National Customer Satisfaction Survey*. Available online: http://www.thehousingforum.org.uk/survey.html

Langridge (2005) Quality can be patchy – that's the snag. *YOUR HOME the Press and Journal*.

Latham, M (1994) *Constructing the team, joint review of the procurement and contractual arrangements in the UK construction industry*, Final Report.

Lorentzen, C (1996) A Challenging View on Building Control. *In: Association of Building Engineers Conference*, Bournemouth.

Mills, T (2000) "Knowing your customers". *In: HouseBuilder*. London: HouseBuilder Publications Ltd.

National Audit Office (2001) *Modernizing construction*, report by the Comptroller and Auditor General. London: The Stationery Office.

Sommerville, J (1994) Multivariate barriers to total quality management within the construction industry. *Total Quality Management*, **5**(5), 289–98.

Sommerville, J, Craig, N and Bowden, S (2004) The Standardisation of Construction Snagging. *Journal of Structural Survey*, **22**(5), 251–8.

Sommerville, J and McCosh, J (2006) Defects in new homes: an analysis of data on 1696 new UK houses. *Journal of Structural Survey*, **24**(1), 6–21.

DRIVERS FOR IMPLEMENTING SUSTAINABILITY INITIATIVES: AN EMPIRICAL STUDY

Suresh Renukappa[1] and Charles Egbu

School of the Built and Natural Environment, Glasgow Caledonian University, Glasgow G4 0BA, UK

In the early part of this 21st century, global competition, the knowledge economy and the potential offered by emerging technologies along with commitment to the principle of sustainability pose profound strategic challenges for business. Sustainability concerns the management of an organization's total business impact upon its immediate stakeholders, the society, and the natural and built environment within which it operates. For businesses, the very concept of sustainability is elusive and defining sustainability in general terms does not easily translate into individual responsibility or appropriate action. Businesses today have to amend many of the principles that have guided generations of managers, and develop a new set of objectives and rules that will enable them to successfully manage sustainability issues in the next decade or so. As organizations try to meet these change challenges, executives face conflicting pressures. The issue is not whether companies will engage economically viable, environmentally sustainable, and socially responsible activities, but why should they do so. For most companies, the central challenge is how best to achieve the maximum environmental and social benefits from a limited amount of resources available for sustainability programmes. Many organizations are convinced that they are likely to financially benefit from encouraging socially and environmentally sustainable business practices. This paper primarily reports on the findings of an ongoing research study, which is focused on how organizations are managing change and knowledge associated with sustainability initiatives so as to improve their competitiveness. The findings are in the main, based on semi-structured interviews with 59 professionals from 40 UK organizations in four sectors: energy and utility, transportation, construction and not-for-profit organizations. It reviews the concept of sustainability and the key drivers for implementing sustainability initiatives in organizations. The paper concludes that identifying and understanding drivers for implementing sustainability initiatives is a complex process. The key drivers for implementing sustainability initiatives as revealed by the study are reducing operating costs, enhancing reputation, stakeholder pressure, Government regulation/legislation, and top management commitment.

Keywords: corporate social responsibility, environmental sustainability, managing change, sustainability initiatives.

INTRODUCTION

Reports in the academic, business and popular press make it clear that the world in which business operates today is different from the world of two to three decades ago. This is primarily due to meeting increased demands and expectations of stakeholders; protecting degradation of natural resources; the knowledge economy; managing crisis and remediation while defending the organization; and diminishing social and community structures (Connor and Mackenzie-Smith 2003). These complex issues involve numerous processes carried out and influenced by many stakeholders to set

[1] Suresh.Renukappa@gcal.ac.uk

the tone and guide corporate level decisions. Nevertheless, to businesses these are formidable environmental and social issues that have evolved over time and that must be addressed (Carroll and Buchholtz 2006). To address the above issues and challenges, sustainability (or sustainable development) offers business leaders a 21st-century management framework. Sustainability is a management principle that aims to create long-term shareholder value by seizing opportunities and managing risks related to the economic, environmental and social impact of doing business (Savitz and Weber 2006).

The World Commission on Environment and Development has defined "sustainability" as "economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Brundtland 1987). However, this macroeconomic definition does not provide much guidance on how this concept should be put into operation at the company level, and managers still question how to implement a strategy to encourage corporate sustainability when there are many competing organizational constraints and numerous barriers to address (Epstein and Roy 2001).

The recent GlobeScan (2005) report states that: "societal expectations for corporate social responsibility have grown across the world. At the same time, corporate social responsibility performance ratings for industry sectors have been consistently decreasing since 2001". Sustainability has significant implications for all businesses. In particularly, it necessitates the need for a decision-making process that balances the impacts associated with environmental, social and economic issues. In order for this to occur, however, the principles of sustainability must be incorporated into existing management systems. Rather than being seen as just another "add-on", sustainability must be viewed as an essential business value that requires full integration into core business strategies (Johnson and Walck 2004).

From a more general perspective, in recent years there has been increasing attention on the drivers of value in organizations. To improve sustainability performance, executives have recognized that it is necessary to better understand the drivers of both costs and revenues and the actions that they can take to effect them. However, the identification and measurement of social and environmental strategies is particularly difficult as they are usually linked to long-term time horizons, a high level of uncertainty, and impacts that are often difficult to quantify (Epstein and Roy, 2001).

Few researchers posit that it is crucial to understand the reasons why corporate decision makers adopt the sustainability initiatives (Hahn and Scheermesser 2006; Dunphy *et al.* 2003; Morrow and Rondinelli 2002; Bansal and Roth 2000; Sharma *et al.* 1999; Henriques and Sadorsky 1999). Even though few authors argue that it is crucial to understand the reasons for transition toward sustainability, there is little empirical research on "why organizations are implementing sustainability initiatives", which is the aim and the research question posed by the authors of this paper.

Understanding the drivers for implementing sustainability initiatives is critical for four reasons. First, this understanding could help business leaders to identify the resulting sustainability-related drivers in their industry and organization. Second, this understanding could act as a much-needed catalyst for stimulating internal discussion and debate about sustainability threats and opportunities in the market and society. Third, this understanding could assist decision makers to develop sustainability strategy based on the drivers. Fourth, this understanding could expose the mechanisms that foster sustainable organizations, allowing managers and decision makers to determine the relative efficacy of actions, market measures and voluntary measures (Grayson and Hodges 2004; Bansal and Roth 2000).

This paper is part of an ongoing research study, which is focused on the management of change and knowledge associated with sustainability initiatives for organizational competitiveness. In the study reported here, four standard industry classification sectors are identified based on the environmental, social and economic accounts of the urban environment. The sectors considered for this study are energy and utility, transportation, construction, and not-for-profit organizations.

For the purposes of this research, sustainability initiatives are defined as “key practices undertaken by an organization to support environmental, social and economic causes and to fulfil organization’s commitments to sustainability”. Causes most often supported through these initiatives are those that contribute to community health (e.g. HIV/AIDS prevention), safety (e.g. crime prevention), education (e.g. job training), and employment (e.g. hiring practices), the environment (e.g., waste recycling), reducing natural resources (e.g. reducing energy consumption) and reducing carbon emission (e.g. minimizing logistics operations).

The paper is organized in the following manner. The next section presents the research aim and method employed for this research. The key drivers for implementing sustainability initiatives are then presented. Finally, the paper concludes with the conclusions and recommendations.

RESEARCH AIM AND METHOD

This paper draws from an ongoing doctoral study entitled “managing change and knowledge associated with sustainability initiatives for organizational competitiveness”. The aim of this research is to investigate how companies are managing change and knowledge associated with sustainability initiatives so as to improve their competitiveness. In order to achieve the aim and objectives of this research, a robust methodology is essential. Broadly, the research process is identified into three key phases within its flexible boundaries. The three phases are the literature review, the pilot study and the main study. The development of the research work started with the literature review. The review of literature involved background study on change management, knowledge management and in varied areas of sustainability. This resulted in the development of a theoretical framework.

In this research study, prior to the main study, a pilot study was undertaken which helped with refining data collection plans with respect to both the contents of the data and the procedure to be followed. As Denzin *et al*. (1998) suggest, when there is a high degree of unpredictability, a pilot study is a good means to add value to the research. A pilot study allowed the researcher to focus on particular areas that may have been unclear previously (Yin 1994). The initial time frame of the pilot study allows the researcher to develop and solidify a rapport with the participant as well as to establish effective communication.

This paper is based on the results from both the pilot (26 interviews from 17 organizations) and the main (33 interviews from 23 organizations) study. Therefore, a total of 59 professionals from 40 UK organizations across 4 industry sectors – energy and utility, transportation, construction and not-for-profit organizations – were interviewed. The current study, which is reported in this paper, was interview-based and semi-structured in format. Semi-structured interviews provide some flexibility and it is one of the ways to obtain a realistic picture of an individual’s view (McCormack and Hill 1997). Those who participated included board members, directors, advisers and managers responsible for corporate environmental, social and economic sustainability initiatives in organizations. The interviews in the current study lasted between thirty and ninety minutes. The format of these interviews was face-to-face. All face-to-face interviews were recorded with permission and later transcribed.

As part of the analysis of the interviews, content analysis was employed. The content analysis begun as a tool for quantitative researchers, now it is increasingly being used in the qualitative studies (Silverman, 2004). Weber (1990) defined content analysis as “a research method that uses a set of procedures to make valid inferences from text”. Applications of content analysis show three distinct approaches: conventional, directed or summative. All three approaches are used to interpret meaning from the content of text data and, hence, adhere to the naturalistic paradigm. The major differences among the approaches are coding schemes, origins of codes, and threats to trustworthiness (Kondracki and Wellman 2002). In conventional content analysis, coding categories are derived directly from the text data. With a directed approach, analysis starts with a theory or relevant research findings as guidance for initial codes. A summative content analysis involves counting and comparisons, usually of keywords or content, followed by the interpretation of the underlying context. The current study adopted a conventional approach to content analysis. Using content analysis enabled the researcher to include large amounts of textual information and systematically identify its properties, e.g. the frequencies of most used keywords in context by detecting the more important structures of its communication content. This paper presents the results from both the pilot and main study on the key drivers that have fuelled the need for implementing sustainability initiatives in the UK organizations.

KEY DRIVERS FOR IMPLEMENTING SUSTAINABILITY INITIATIVES

Table 1 shows the key drivers for implementing sustainability initiatives as revealed in this study.

Table 1: The key drivers for implementing sustainability initiatives as cited by interviewees

Sl. No	Key driver for implementing sustainability initiatives	Percentage of interviewees cited
1	Reducing operating costs	97 %
2	Enhancing reputation	90 %
3	Stakeholders’ pressure	83 %
4	Government regulation/ legislation	76 %
5	Top management commitment	73 %

From the data in Table 1, it is evident that the key drivers for implementing sustainability initiatives are reducing operating costs, enhancing reputation, stakeholders’ pressure, Government regulation/legislation, and top management commitment. It should be noted that for some organizations, the key drivers may be all of these drivers or combination of some of these drivers.

Reducing operating costs

Regardless of industry, the main aim of any organization is to: create compelling new product and service offerings; provide service quality and value as defined by customers; generate attractive returns for shareholders; be the best place to work for employees; operate mutually value-creating partnership with supply chain; and act in an ethically, socially and environmentally responsible way (Hayler and Nichols 2007). Running the business includes reducing the costs, improving productivity, eliminating needless waste and obtaining capital at lower cost.

In the current study, 57 of the 59 (97%) interviewees agreed that the key driver for implementing sustainability initiatives is to reduce operating costs. A number of interviewees raised the concerns for increasing fuel price, amount of money they are paying for managing waste, and difficulties in recruiting skilled employees. One of the interviewees noted:

> "One of the key drivers for our business is to minimize operating costs. Therefore, we implemented sustainability initiatives like energy savings and waste management initiatives five years back".

Furthermore, this interviewee noted how their organization is experiencing cost savings particularly from energy savings and waste recycling. In response to the above, it is clear that if firms persist with the win-win business logic of 'natural capitalism', profiting from increasing the productivity of natural resources, closing materials loops and eliminating waste, shifting to biologically inspired production models, providing their customers with efficient solutions, and reinvesting in natural capital, they can gain a commanding competitive advantage (Lovins *et al.* 1999).

A longitudinal study of the Canadian oil and gas industry showed that proactive strategies of environmental responsiveness were a reflection of managerial interpretation of environmental issues as opportunities (Sharma 1997). Embracing environmental and social issues as opportunities enables managers to reap benefits in terms of lower costs, higher process efficiencies, reuse and recycling of resources, and a positive reputation (Sharma and Vredenburg 1998; Post and Altman 1994).

Eco-efficiency and socio-efficiency are the basic components of sustainability (Savitz and Weber 2006). For example, eco-efficiency initiatives can allow the firm to reduce the amount of resources used to produce products and services, which in turn decreases an organization's operating cost while decreasing its environmental impact. Also, it will coordinate the environmental activities of the firm to achieve greater organizational efficiency and effectiveness. The underlying theme of eco-efficiency is simple: pollution is waste, and waste is anathema because it means that organization is paying for something it did not use.

Enhancing reputation

The motivation from the corporate sector to take part in sustainable development may come from several concerns, such as branding and reputation (Fombrun 1996), enhancing competitive advantage (Porter and Kramer 2002), embracing stakeholders that are key to success and long-term value maximization (Freeman 1984).

The PricewaterhouseCooper's (2002) survey report found that 90% of companies believe that sustainability is important to their reputation. The results of this current study support PricewaterhouseCooper's (2002) global survey findings.

In this research, 53 of the 59 (90%) interviewees agreed that another key driver for implementing sustainability initiatives is to enhance their organization reputation. Due to the recent spate of worldwide corporate scandals, most of the interviewees highlighted the risks of irresponsible behaviour and governance to damaged reputations, brands and, in some cases, the demise of companies. This was the second most important driver identified by the interviewees in this research. None illustrates this point better than the response by the corporate responsibility director who said:

> ‘‘We merely realize that our image could be adversely affected if we were seen to conduct our business in socially irresponsible way. There is no doubt sustainability offers terrific opportunity for us to create and maintain positive image in the society. Acting in an environmentally sustainable and socially responsible way is one of our organization’s values and is firmly anchored in our culture. …we touch millions of lives everyday because of the nature of the industry we are in. Acting responsibly should be fundamental to how we carry out every aspect of our business. To deliver a sustainable future, we are investing in new technologies such as clean coal and carbon capture, as well as in the next generation of renewable energy sources. We provide extra support for our customers facing fuel poverty, and those who are particularly vulnerable. We aim to encourage employees’ development, recognize their achievement and look after their wellbeing. We have in place a number of policies that seek to foster and maintain our well-earned reputation for integrity and responsible business conduct”.

From the above statement, it is clear that some businesses are facing threat from the so-called ‘bottom-line’ backlash, which can adversely affect corporate reputation, especially when profits and the levels of executive compensation that accompany them are seen to be gained at the expense of other stakeholders (Porritt 2005). It is just such a situation that underlay scandals like Enron and has led the financial services industry in the UK into a soul-searching exercise over its governance models and compensation strategies (Gordon 2004).

Regardless of how the balance between environmental, social and economic responsibility issues is struck and changes over time, core items on this agenda for most organizations will include building and maintaining strong corporate reputations and corporate brands. These issues are especially important among economies and companies that rely on intangible assets such as creativity, innovation, intellectual capital and high levels of service as the basis for competition (Kay 2004).

Balmer and Greyser (2003) noted “corporate reputation is a window to the fundamental character of a company and its leaders, and as such is relevant to all stakeholders”. Management can choose to proactively shape and nurture its corporate reputation or become the victim of assailant’s negative reputational arrows.

Stakeholder pressure

In recent years, business stakeholders of all kinds have become increasingly interested in and engaged with businesses to address environmental and social issues. Despite the poor image and bad press of business in recent times, a recent survey suggests that people retain a faith in the ability of businesses to provide a positive contribution to society (Business in the Community 2005).

The most significant change in recent time is the emergent role of stakeholders, beyond shareholders, in defining the roles and responsibilities of business in society (Frooman 1999; Harrison and Freeman 1999; Goodpaster 1991). Many stakeholders have interests far beyond the traditional ideas of corporate philanthropy and the prevention of negative business impacts (Frooman 1999). Indeed, such stakeholders increasingly requiring businesses, especially large organizations, to be a positive force, to contribute to broader societal development goals and to work in partnership with others to solve humanitarian crises and endemic problems facing the world such as disease and poverty, climate change and environmental stewardship (Godet 1998).

In this current study, 49 of the 59 (83%) interviewees agreed that the stakeholders' pressure is a key driver for implementing sustainability initiatives. The most concerned stakeholders are employees, trade unions, suppliers, customers and NGOs. Each group has its own concerns for society and the environment. One of the respondents stated:

> "It is certainly important to recognize the needs of the stakeholders. In recent time, there is a strong environmental and media lobby against our industry. Some of the pressure can be extreme and disgraceful claims…. To mitigate business risk, management expects us to provide more and more information about the environmental and social impact of our business than our financial performance".

A number of interviewees highlighted the difficulty in prioritizing the interests of stakeholders. If organizations have to react to external pressures there is a greater sense of conflict between economic and social objectives. As McWilliams and Siegel (2001) noted, if the firm is functioning properly with respect to prioritizing the interests of stakeholders, then management should pursue only those strategies designed to enhance or protect the firm's position across its relevant markets.

Government regulation/legislation

Governments clearly plays a major role in environmental and social sustainability by the provision of environmental and social standards and regulatory frameworks to conserve productive inputs and the quality of life, in an economic environment where such action may be regarded as cost enhancing and detrimental to industrial competitiveness. Such additional costs no doubt cause very real problems to industry in the short term, particularly if adequate preparatory work has not been completed, but in the longer term: properly designed environmental standards can trigger innovations that lower the total cost of a product or improve its value. Such innovations allow companies to use a range of inputs more productively – from raw materials to energy to labour thus offsetting the costs of improving environmental impacts and ending the stalemate (Porter and Van Der Linde 1995).

Regulatory pressure to cut waste and emissions is one of the main drivers for business interest in sustainability. For example, the UK landfill tax was introduced at £7 per tonne for active waste and £2 per tonne for inert waste in October 1996. In the 2000 Finance Act, the UK Government introduced the climate change levy as part of its wider climate change programme. It was regarded as the 'UK's most significant green tax to date' and was estimated to raise £1 billion in revenue and save 2 million tonnes in carbon dioxide emissions per year by 2010 (Varma 2003). In this research, one of the interviewee stated that:

> ''The greatest impact on us recently has come through the UK government climate change policy".

In this current study, 45 of the 59 (76%) interviewees agreed that another key driver for implementing sustainability initiatives is due to government regulation/legislation. For example, one of the managing directors noted:

> "…the organization has got climate change and waste management pressures that we have to deal with. We also have issues around things like using

> renewable energy and fuel cost. Along with this is the huge government legislation around things like gender, age, race and employment".

A UK-based study (Faruk 2002) had similar findings: 79% of 700 senior business managers surveyed cited government legislation or threat of legislation, as the main reason for implementing environmental sustainability initiatives. The results of this current study support Faruk (2002) findings.

In the current study, many organizations are regulatory compliance by voluntarily developing and certifying their environmental management systems under ISO 14001 guidelines.

Top management commitment

An organization's sustainable operation requires strategies and policies that result in fully integrating the organization's social and environmental functions with business management systems. The ultimate success of any sustainability initiative is found when sustainability-based thinking, perspective and behaviour are incorporated into the everyday operating procedures and culture of an organization (Doppelt 2003). Therefore, the role of senior management is important.

Porter (1991) noted that strategy is the act of aligning a company with its business environment to maintain a dynamic balance. Thus, leadership strategy will be the key. For developing, implementing and sustaining the sustainability-related strategy that changes systems or transitions from traditional resource-intensive to an approach that uses fewer resources and maximizes benefits to both organization and stakeholders requires leadership, culture, management commitment, resources and innovation (Placet *et al.* 2005).

Also, Henriques and Sadorsky (1999) suggest that what an organization is actually doing, or has done, in relation to environmental issues can describe its commitment to the natural environment. Previous researchers suggest that socially proactive companies have top management support that is involved in environmental issues, utilize internal and external environmental reporting, and employee environmental training and involvement is encouraged (Bansal and Roth 2000; Clarkson 1995; Hunt and Auster 1990; Carroll 1979).

In this research, 43 of the 59 (73%) interviewees noted that another key driver is top management commitment. One of the senior board members noted that "sustainability initiatives are driven 80% by head office and 20% by individuals within the company".

To achieve sustainability goals, there is a need for a strong agenda to support sustainability initiatives in a more holistic and integrated approach to environmental, social, and economic concerns. In particular, business leaders will need to reassess their role, specifically their responsibility in persuading organizations to adopt practices that support a sustainable approach. Therefore, leadership from top plays an important role in addressing sustainability issues and concerns. At all levels, advocates of sustainability need to be co-ordinators, mentors and integrators, linking capabilities into organizational structure, technologies and practices of organizations (Doppelt 2003).

CONCLUSION

Sustainability is about building a society in which a proper balance is created between economic, social and environmental aims. For businesses, effectively managing sustainability initiatives could lead to the creation of new ways of working, new products, services, and new market space. To improve organizational sustainability performance, executives have to recognize and better understand the drivers of both costs and revenues and the actions that they can take to address them.

This paper has outlined the key drivers that increasingly fuel the need for implementing sustainability initiatives. A background to sustainability, research aim and method has also been documented. The current study findings suggest that a significant change in organizational strategy toward sustainability was triggered by political, economic, social and environmental changes. As revealed from this study, a complex mix of forces drives organizations to implement sustainability initiatives. The key drivers that have fuelled the need for implementing sustainability initiatives are reducing operating costs, enhancing reputation, stakeholder pressure, Government regulation/legislation and top management commitment. It should be noted that for some organizations the key drivers may be all of these drivers or combination of some of these drivers.

The current study reveals that, even though, most businesses now recognize that sustainability is conceived as a holistic and integrative concept, there are considerable ambiguities and interconnectivities among various facets of environmental, social and economic sustainability issues. The paper concludes that identifying and understanding drivers for implementing sustainability initiatives is a complex process. Given that the research reported on in this paper was largely exploratory in nature, the results presented here are only tentative and of limited value for the purpose of generalization. Therefore, additional research with more elaborate and better-articulated designs is therefore called for to explore further the complex mix of key drivers that have fuelled the need for implementing sustainability initiatives.

REFERENCES

Balmer, J T and Greyser, S A (2003) *Revealing the corporation: Perspectives on identity, image, reputation, corporate branding and corporate-level marketing*. London: Routledge.

Bansal, P and Roth, K (2000) why companies go green: a model of ecological responsiveness. *Academy of Management Journal*, **43**(4), 717–36.

Brundtland, G (1987) *Our common future: The World Commission on Environment and Development*. Oxford: Oxford University Press.

Business in the Community (2005) Community Statistics and Facts. Available online: www.bitc.org.uk

Carroll, A B (1979) A Three-dimensional Conceptual Model of Corporate Social Performance. *Academy of Management Review*, **4**, 497–505.

Carroll, B A and Buchholtz, K A (2006) *Business and Society - Ethics and Stakeholder Management*. South-Western.

Clarkson, M (1995) A stakeholder framework for analysing and evaluating corporate social performance. *Academy of Management Review*, **20**(1), 92–117.

Connor, R and Mackenzie-Smith, P (2003) The Leadership Jigsaw – Finding the Missing Piece. *Business Strategy Review*, **14**(1), 59–66.

Denzin *et al*. (1998) *Strategies of qualitative inquiry*. Sage Publications.

Doppelt, B (2003) Sustainability, governance and organisational change. *In: Leading Change toward Sustainability*. Greenleaf Publishing.

Dunphy, D *et al*. (2003) *Organizational Change for Corporate Sustainability*. London: Routledge.

Epstein, M J and Roy, M J (2001) Sustainability in Action: Identifying and Measuring the Key Performance Drivers. *Long Range Planning*, **34**, 585–604.

Faruk, A (2002) Corporate responsibility: beyond niceness. *Directions*, *The Ashridge Journal*, summer. Available online: www.ashridge.com

Fombrun, C (1996) *Reputation: Realising Value from the Corporate Image*. Harvard, MA: Harvard Business School Press.

Freeman, R E (1984) *Strategic Management: A Stakeholder Approach*. Boston: Pitman, Harper Collins.

Frooman, J (1999) Stakeholder influence strategies. *Academy of Management Review*, **24**, 191–205.

GlobeScan (2005) Corporate social responsibility monitor: global public opinion on the changing role of companies. Available online: www.globescan.com (accessed 10 January 2006).

Godet, M (1998) Sustainable development: With or without mankind. *Futures*, 30(6).

Goodpaster, K E (1991) Ethics and stakeholder analysis. *Business Ethics Quarterly*, **1**(1), 53–72.

Gordon, J N (2004) What Enron means in the management and control of the modern business corporation: some initial reflections. *In:* T Clarke (Ed.) *Theories of corporate governance: the philosophical foundations of corporate governance*. London: Routledge.

Grayson, D and Hodges, A (2004) *Corporate Social Opportunity: Seven Steps to Make Corporate Social Responsibility Work for Business*. London: Greenleaf Publications.

Hahn, T and Scheermesser, M (2006) Approaches to corporate sustainability among German companies. *Corporate Social Responsibility and Environmental Management*, **13**, 150–65.

Harrison, J S and Freeman, R E (1999) Stakeholders, social responsibility, and performance: empirical evidence and theoretical perspectives. *Academy of Management Journal*, **42**(5), 479–85.

Hayler, R and Nichols, D M (2007) *Six Sigma for financial services: How leading companies are driving results with lean, six sigma, and process management*. New York: McGraw-Hill.

Henriques, I and Sadorsky, P (1999) The Relationship between Environmental Commitment and Managerial Perceptions of Stakeholder Importance. *Academy of Management Journal*, **42**(1), 87–99.

Hunt, C and Auster, E R (1990) Proactive environmental management: avoiding the toxic trap. *MIT Sloan Management Review*, **31**(2), 7–18.

Johnson, D and Walck, C (2004) Certified success: integrating sustainability into corporate management systems. *Journal of Forestry*, (July/August).

Kay, J (2004) *The truth about markets: why some nations are rich but most remain poor*. London: Penguin.

Kondracki, N L and Wellman, N S (2002) Content analysis: review of methods and their applications in nutrition education. *Journal of Nutrition Education and Behaviour*, **34**, 224–30.

Lovins, A *et al*. (1999) A road map for natural capitalism. *Harvard Business Review,* (May–June), 145–58.

McCormack, B and Hill, E (1997) *Conducting a Survey*. London: International Thomson Business Press.

McWilliams, A and Siegel, D (2001) Corporate Social Responsibility: a theory of firm perspective. *Academy of Management Review*, **26**(1), 117–27.

Morrow, D and Rondinelli, D (2002) Adopting Corporate Environmental Management Systems: Motivations and Results of ISO14001 and EMAS Certification. *European Management Journal*, **20**(2), 159–71.

Placet, M *et al*. (2005) Strategies for sustainability. *Research Technology Management*, **48**(5), 32–41.

Porritt, D (2005) The reputational failure of financial success: the 'bottom line backlash' effect. *Corporate Reputation Review*, **8**, 198–213.

Porter, M E (1991) Towards a dynamic theory of strategy. *Strategic Management Journal*, **12**, 95–117.

Porter, M E and Kramer, M R (2002) The competitive advantage of corporate philanthropy. *Harvard Business Review*, **80**(12), 56–68.

Porter, M E and Van Der Linde, C (1995) Green and Competitive: Ending the Stalemate. *Harvard Business Review*, 73(September–October), 120–34.

Post, J E and Altman, B W (1994) Managing the environmental change process: Barriers and opportunities. *Journal of Organizational Change Management*, **7**(4), 64–81.

PricewaterhouseCoopers (2002) *Sustainability Survey Report*. Available online: www.pwcglobal.com

Savitz, A W and Weber, K (2006) *The Triple Bottom Line*. San Francisco, CA: Jossey-Bass.

Sharma, S (1997) A longitudinal investigation of corporate environmental responsiveness: antecedents and outcomes. *Academy of Management Best Paper Proceedings***,** 460–4.

Sharma, S *et al*. (1999) Corporate environmental responsiveness strategies: The importance of issue interpretation and organisational context. *Journal of Applied Behavioural Science,* **35**, 87–109.

Sharma, S and Vredenburg, H (1998) Proactive Corporate Environmental Strategy and the Development of Competitively Valuable Organizational Capabilities. *Strategic Management Journal*, **19**(8), 729–53.

Silverman, D (2004) *Qualitative research: theory, method and practice*. London: Sage Publications.

Varma, A (2003) UK's Climate Change levy: cost effectiveness, competitiveness and environmental impacts. *Energy Policy*, **31**, 51–61.

Weber, R P (1990) *Basic Content Analysis*. Newbury Park, CA: Sage Publications.

Yin, R K (1994) *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage.

ASSESSING ATTITUDES TO SUSTAINABILITY IN CONSTRUCTION AND PROPERTY MARKETS

Danny Myers[1] and Mutale Katyoka

Faculty of the Built Environment, University of the West of England, Bristol, BS16 1QY, UK

In the last 25 years, sustainable development has emerged as an important international issue, and most Governments have adopted a policy to meet the agenda. On the basis of public disclosures made by major construction and property companies, this research reviews current attitudes to sustainability and corporate social responsibility. The bulk of the sample is derived from companies listed on the UK Stock Exchange; however, for comparative purposes, a smaller subset is examined from equivalents in Brazil and South Africa. The main findings suggest that construction and property companies do not positively embrace new ideas; consequently, relatively few have changed their business paradigm to one that is heavily influenced by sustainability. An argument that emerges is in favour of a broader industrial category to integrate construction, real estate and management of built facilities, at both the intra and international levels. The paper concludes that it is the fragmented, diverse and heterogeneous nature of the construction and property sectors that presently restricts the transition towards the adoption of sustainable practice. This is the crux of the problem to resolve in the future.

Keywords: construction sector, corporate social responsibility, integration, real estate, sustainable development.

INTRODUCTION

In December 1983, the Secretary-General of the United Nations set up an independent commission to address the long-term environmental strategies for achieving sustainable development by the year 2000 and beyond. The subsequent World Commission on the Environment and Development (WCED), chaired by Gro Harlem Brundtland, published its report *Our Common Future* in 1987.

The Commission's hope for the future was conditional on immediate political action to manage environmental resources to ensure both sustainable progress and human survival. As stated in the foreword: “We are not forecasting a future; we are serving a notice - an urgent notice based on the latest and best scientific evidence - that the time has come to take the decisions needed to secure the resources to sustain this and coming generations. We do not offer a detailed blueprint for action, but instead a pathway by which the peoples of the world may enlarge their spheres of cooperation” (WCED 1987: 2).

Interestingly, nearly 25 years later the landmark Stern Review (2007) reiterated similar messages. It highlighted the global problem of greenhouse gases and encouraged society to move from a business as usual model towards a strategy aimed at guaranteeing a future for the planet earth. The crux of the argument was based on a risk analysis where Stern recommended that we need to spend 1% of world GDP

[1] Danny.myers@uwe.ac.uk

immediately to avert a 20% decline in world GDP in the next 25 years. As he expressed it in the introduction to his report: “The scientific evidence that climate change is a serious and urgent issue is now compelling. It warrants strong action to reduce greenhouse gas emissions around the world to reduce the risk of very damaging and potentially irreversible impacts on ecosystems, societies, and economies. With good policies the costs of action need not be prohibitive and would be much smaller than the damage averted” (Stern 2007: xiii).

The implication of the calls for sustainability for the construction and property sector are immense, as they both make such large and important contributions to the economic and social character of society. These industries not only help to determine the nature, function and appearance of our towns and countryside, but also they influence the levels of productivity achieved in commercial settings, contribute to the formation of communities and have significant environmental impacts. The importance of the sustainability messages for property and construction, therefore, cannot be overstated.

The business strategy that is firmly imbedded in both sectors, however, appears in many instances to be more than 50 years out of date. Evidence of the conservative and traditional nature of the construction and property sectors are frequently made in government reports and sponsored commentary. For example, Fairclough (2002: 30) accused the construction industry of being “dirty, dangerous and old fashioned”; the property sector was warned of the need to “make a prompt effort to ditch the cynicism that has typified the sector to date, and acknowledge that the business environment has changed significantly in recent years” (SCTG 2001: 1). In other words: the sectors can easily be singled out from the rest of the economy by attitudes, technologies, processes and cultures that are at least half a century old (Dulaimi *et al*. 2001: 1).

Consequently, there are relatively few companies in the real estate or construction sectors that genuinely embrace sustainability, corporate social responsibility (CSR) socially responsible investment (SRI) or any of there equivalents; and this inertia has survived despite the fact that explicit strategies to promote sustainable construction have emerged across many European, American and African states (Myers 2004: 236). The Government-led strategies have occurred for two reasons, firstly because of the significant environmental and social impacts created by the industry and secondly, and more importantly, because it always lags so far behind all the other sectors. A similar case could be made for property but in some ways this gets subsumed under the heading construction.

The intention of this paper is to argue that for a sustainable built environment (and, by default, sustainable development) to become a reality, it is necessary to promote more than just policy aimed at the construction stage. The built environment clearly straddles a number of disciplines and it seems ironic that, to date, most related government policy and academic research has primarily focused on the construction of new buildings. As a general rule of thumb, new builds only represent around 1% of the total stock in any one year, so it could take at least 100 years to completely replace current stock. Even more worrying is the fact that, although the technology exists to design new stock in ways that could reduce the waste stream and energy consumption by 50% or more, most new builds (about 0.9%) achieve little more than the minimum standards laid down in the building regulations. Thus, without a cultural shift and interventions from governments, it could take 1,000 years to replace the stock with the best possible performance at today’s standards! Consequently, there is an argument that favours the retention of existing buildings on the basis that they can be retrofitted and this process is less polluting than the construction of new buildings.

THE RESEARCH METHODOLOGY

The research involved a systematic review of the contents of annual reports (public disclosures) published by major construction and property companies during the financial year of 2005. The objective was to determine attitudes to sustainability and in a large part this was gauged by the reporting of corporate social responsibility and associated issues. In some cases, the related strategy was fully disclosed (revealed) in a separate report.

All public limited companies (PLCs) are legally obliged to produce and make available to the public an annual report and set of accounts. Over time, the publication of these disclosures has become a public relations exercise in which the company details it achievements to date and clarify its future missions. In short they are documents published to inform, and impress, interested stakeholders; in particular investors (shareholders).

As a research metric, the process of content analysis of company disclosures is objective, consistent and repeatable; and it avoids the problems of subjectivity associated with other methods of research. It is, in fact, the dominant method used to inform the *Global Reporters* series. This biennial survey of corporate sustainability is coordinated by Sustainability (an international consultancy promoting the business case for sustainable development) with support from the United Nations Environment Programme (UNEP), and Standard and Poor’s (the international risk assessment and credit ratings agency). Together they have produced four reports since the series commenced in 2000. Each publication in the series uses content analysis to identify best practice in corporate accountability across the triple bottom line of sustainable development to select the top 50 international companies. (The only construction or property company listed to date in this top league is Lafarge, the French materials and construction company.) It is also interesting to note that a third of the Dow Jones Sustainability Index assessment criteria are based upon “disclosures written by the company themselves” (Cerin 2002: 50). Those seeking inclusion in the FTSE4Good index are also subject to: “scrutiny of annual reports, and research of company websites” alongside company questionnaires and direct contact (FTSE 2006: 4).

Content analysis of public disclosures also formed the basis of the World Wildlife Fund (WWF) research that was associated with their campaign for one million sustainable homes to be completed by 2012. The aim was to move sustainability from the fringes to the mainstream of UK housing, and the study restricted itself to 13 UK listed house-builders (WWF 2004). The majority of their findings were based on the examination of public disclosures for the financial year ending 2002. These showed house-builders to be slightly ahead of the game and this relative position could be equally inferred from the 2005 data. Regardless it would appear that none of them has embraced sustainability in its entirety.

A firm that genuinely embraced the idea of CSR would use it to: manage the effects of globalization, to cut environmental costs, raise productivity, and improve staff recruitment and retention rates (Hancock 2005: 6). They would be wholly committed to sustainability in so far as they would seek to grow the business by integrating the environmental, social and economic dimensions of their corporate activities. More importantly, from the view of measuring this commitment, they would be able to cite examples of good practice and refer to third party certification to confirm their social and environmental credentials. In Henriques and Richardson's (2004: xix) words, they would be "connected and responsive to shareholders, suppliers, communities and customers". In short, there is no 'one-size-fits-all' guide for what CSR should mean – but firms embarking on the commitment would innovate and think beyond the traditional business paradigm.

Most firms involved in the built environment, however, have not progressed much beyond the starting line, where they simply pay homage to the environment and community by entering into a passive box ticking exercise that implies some awareness but is lacking in evidence. In other words, CSR has not yet developed to the point where it is linked to corporate performance.

For example, in a pilot survey based on company reports published in 2003, there appeared to be very few PLC's listed in the UK construction and building sector that fully embraced or even addressed CSR issues. From the sample of 42 companies, the majority appeared completely traditional in the sense that they only reported financial information. In sharp contrast, however, there was a small emergent group of companies who produced some kind of "stakeholder reports" to address their commitment to the environment, the community, employees, customers, suppliers and/or investors. This group only accounted for approximately one quarter of the sample and interestingly the majority of them were in fact companies that gained more than 25% of their turnover from house building. Overall, the percentage of material relating to CSR in the pilot sample was found to be less than 5% (Myers 2005).

The construction and property research findings for 2005 are dealt with as discrete parts in the following sections

CONSTRUCTION FINDINGS

A sample of 31 companies was selected on the basis that they were listed in the FT 'building and construction' sector and subscribed to the *Financial Times* service between March and August 2006. This number represented 42% of the 74 companies listed in the sector by the Stock Exchange at that time. Alongside this core information, any supplementary information, available from the companies' websites, was also reviewed. The results are summarized in Table 1

Table 1: Construction 2005 – UK

Number of sample companies	31
Total page count of annual reports	3036
Proportion of pages relating to CSR	5.8%
Companies publishing a separate CSR report	55%

As the data in Table 1 suggests, in quantitative terms the construction and building sector appear to be modernizing. According to 2005 data, more than half of the sample produced a separate report on issues of CSR – and a significant proportion actually allude to it, albeit quite briefly in the main report.

A further audit of the construction and building sector was carried out in Brazil as a kind of control, and this revealed a far lower degree of participation in CSR, as summarized in Table 2.

Table 2: Construction 2005 – Brazil

Number of sample companies	14
Total page count of annual reports:	374
Proportion of pages relating to CSR	0.8%
Companies publishing a separate CSR report	21%

As the data in Table 2 suggests, in a developing country such as Brazil (adopting World Bank classifications) the construction and building sector are still relatively traditional as less than 1% of the reports allude to CSR and only 21% of the companies examined actually produced a separate report on these issues.

PROPERTY FINDINGS

A sample of 46 companies was selected on the basis that they were listed in the FT 'real estate sector' and subscribed to the *Financial Times* service between March and May 2006. This number represented 37% of the 125 companies listed in the sector by the Stock Exchange at that time. Alongside this core information, any supplementary information, available from the companies' websites, was also reviewed. The results are summarized in Table 3.

Table 3: Property 2005/06 – UK

Number of sample companies	46
Total page count of annual reports	3865
Proportion of pages relating to CSR	1.5%
Companies publishing a separate CSR report	13%

As the data in Table 3 suggests, the UK property sector appear in relative terms to be lagging behind the profile suggested for construction. Many companies were still only providing traditional financial reports with some token references to CSR made here and there. The sample only showed 13% of the companies producing a separate report in 2005.

A subsequent audit of the property sector was carried out in South Africa and the results are presented in Table 4.

Table 4: Property 2005 – South Africa

Number of sample companies	22
Total page count of annual reports	1293
Proportion of pages relating to CSR	0.8%
Companies publishing a separate CSR report	5%

The data in this final table shows the weakest position regarding CSR reporting. South Africa (classified as a developing country by the World Bank) has a traditional property sector. Less than 1% of the reports allude to CSR and only 5% of the companies examined produced a separate report on the issue.

Overall, the percentage of material relating to CSR in the samples was found to be less than 3%; in short, no more than 'window dressing'.

CSR findings

The main purpose of CSR reporting is to inform stakeholders of a company's environmental, social and economic performance, and the argument being pursued in this research is that it can be used as a means of measuring a company's progress towards sustainability. The problem, however, is to differentiate between those who approach sustainability as a PR exercise and those who are genuinely committed; a line needs to be drawn between those who ‘green-wash’ their products and those who actually ‘walk the talk’.

As the data in the tables suggests, in the property sector there are very few on either side of that divide line; real estate companies appear to be traditional with a majority reporting only financial information. In contrast, the construction sector is relatively further along the spectrum, with some companies offering a separate report on issues of CSR and, in some exceptional cases, making real inroads with evidence and examples of best practice. Carillion PLC, for example, refers to a sustainability policy that dates back to 1994, and this has been continually revised and influenced by the Natural Step Framework, an international system designed to achieve sustainable development. Sustainability has clearly become an integral part of Carillion’s business plan as it states: “it is as important to deliver the intangible issues, as it is to deliver hard-nosed cash backed business objectives. In fact it has been seen that community and environmental objectives both enable and legitimize the success of our business objectives in a process of continual improvement” (Carillion 2006). Likewise Skanska, the Swedish construction firm, has adopted four ‘zero’ targets to focus its sustainable development achievements: zero loss-making projects, zero environmental incidents, zero work site accidents and zero ethical breaches. Also in the 2005 annual report, it proudly details its association with the development of housing that uses environmentally sound materials and production methods to significantly lower the life cycle costs of the buildings (Skanska 2005: 40).

Between the two extremes, in all continents are companies that are just beginning to engage in social and environmental issues. This might amount to no more than a couple of sentences on CSR whilst others would have as many as 10 pages; contributing from as little as 1% to as much as 20% of the content, in South Africa and the UK respectively.

The lack of engagement is not particularly surprising as the conventional goal of any company is to maximize profits. As the supporters of traditional market economics are keen to emphasize, ‘There is one and only one social responsibility of business – to use its resources and engage in activities designed to increase its profits’ (Friedman 1962). CSR, however, does not seek to challenge this convention but to create conditions where social and environmental benefits can simultaneously help to drive the business forward. In Elkington’s (1994) elegant phrase, “triple bottom line accounting” must find resonance with the business community for sustainability to be realized. Interestingly triple bottom line accounting have been undertaken for two of Carillion’s PFI projects and these clearly demonstrate the financial gains that can be made from accounting for the social and environmental impacts made during the long concession periods (Casella Stanger 2002).

CIRCLE OF BLAME

Construction work inevitably involves the assembly of a range of materials and services from a broad range of sources. In turn, each of the material inputs is subjected to different types of processing according to their particular use on a specific project. Assembling the materials are teams of subcontractors gathered for the sole purpose of completing the project. As a result, the labour force is often more than one stage removed from the agreement made between the client and the developer; in fact, the whole process is characterized by its temporary and relatively short-term nature. A common analogy that is used compares the process of construction to film production to emphasize that each project involves gathering together a different team to build a 'unique' product (Ive and Gruneberg 2000: 149). It is this diverse and fragmented nature of the industry that constrains the opportunities to improve performance, learn from experience and introduce innovation. Furthermore, the division of labour in the industry leads professions to defend their traditional interests against emergent trends and this hinders communications and the transfer of knowledge. As Gann (2000: 237) observed: "professions and industry associations are just as likely to cause inertia to change as they are to promote innovation". It is clear to see how these aspects of construction and property development lead to difficulties in approaching sustainable development in a coherent manner.

No one specific sector should be allowed to carry all the blame for the failings of this system, as it is some challenge to integrate all the related sectors in a common vision – especially as there is a lack of joined-up thinking across the various related government departments. The problem is compounded further by a mindset that tends to fragment the responsibility for sustainable development. Construction firms argue that they can only adopt holistic approaches if clients ask for them; since builders carry out the instructions of their paymasters. Property developers are often restricted by the conditions imposed by investors or banks, and they tend to be risk-averse and hesitant to fund new ventures. Architects are constrained by planners and the users of buildings have their own specific requirements. The so-called 'circle of blame' that perpetuates the existing traditional approach highlights the conservative nature and adversarial tendencies that make up the relationships in the property and construction markets.

CONCLUSIONS

It is important to emphasize that the survey data referred to above, is based on publicly available information from: the *Financial Times* Annual Report Service; ShareData online, a database of companies listed on the Johannesburg Stock Exchange; and Bovespa, the Brazilian stock exchange in Sao Paulo. This enabled an audit of 31 construction and 46 property majors listed on the UK Stock Exchange and 22 property and 14 construction companies listed on stock exchanges in developing countries.

The largest part of these two markets, however, always comprises small firms; far smaller than those audited. For instance the DTI register lists more than 183,000 private construction contractors working in Great Britain – and approximately 85% of them employ less than eight people with a significant proportion being self employed (DTI 2006). The nature of the property sector is different, the smaller firms are usually partnerships and the larger ones are PLCs employing thousands of people; the common structure for the majority of real estate firms will be some form of limited liability, and there are currently more than 153,000 companies listed in the sector in Great Britain (Companies House 2007). These statistical portraits appear to be very similar to the structure of firms that make up construction and property across other continents (Carassus 2004). The important point of these statistics, however, is to highlight that the typical firm in the property and construction sector is the small private firm and they are quite likely to have incomplete records and far less grand corporate strategies. The government will be lucky if they report fully on their financial position let alone their social and environmental progress.

On the basis of publicly available information, and related literature, the survey suggests that some of the exceptionally large companies in the construction sector are beginning to acknowledge sustainability; and to a lesser degree the same applies to real estate. These firms, at the forefront of the sectors, recognize that a business is no longer judged solely on the economic value added by a company's activity, it is also judged on the social and economic value they add (or destroy). Examples of best practice to minimize the negative impacts and develop the obvious business opportunities are stated in their reports. However, it also clear that many companies, particularly the small, unlisted ones, have a long way to go, before they can effectively manage the opportunities that emerge from the sustainability agenda.

This rather negative portrait is partly due to the inefficiency of construction and property markets. Construction tends to be short-term in outlook, slow to innovate and hesitant to adopt best practice. Compounding the problem, the market for tenants of property in the commercial sector is subject to long-term leases, with large developers supplying a standardized product on a kind of 'let and forget' basis. In the residential sector, market conditions are little better, because in most instances, occupiers have limited control of the design and build specifications of the homes they buy or rent. In consequence, the users of buildings – the real customers – have become disconnected from the development process.

Compounding the problem is the diverse nature of these two sectors in terms of both the associated processes and the related professions. Indeed, when Professor Pearce, an environmental economist (and Government adviser on sustainable development), was commissioned to investigate the social and economic value of construction, he was struck by the complexity of the sector and its lack of comparable international data. His report argued that before the industry can proceed towards contributing to sustainable development it needs to adopt a more holistic definition to include property and its management. He stressed that sustainability is concerned with the complete life cycle, so a building needs to be considered from its design and construction, through the operational stage, to its deconstruction. To make meaningful recommendations, therefore, "it is necessary to understand the nature of the industry – its size and structure" (Pearce 2003: ix).

The need to broaden the approach to the construction and property sectors has been reiterated by the International Council for Research and Innovation in Building and Construction. Carassus (2004) and his team, reviewed nine countries, employing a new systems approach to all that construction entails. The case was made to broaden the approach, to emphasize the importance of repair, maintenance, and management of existing structures and buildings. To paraphrase their conclusions: the requirements of sustainable development call for a new approach to the economic analysis of the construction and property markets to take into account all the participants involved in the life cycle of building structures; not only design and construction but also operation, maintenance, and the management of services provided by built facilities. This new broad approach would provide a framework for sustainable development, not only in terms of analysis but also in terms of public regulation. They then close with the apt remark that the separation of construction economics from property economics has become 'obsolete' (Carassus 2004).

To sum up, it is the existing systems of industrial classification (NACE, NAICS, ISIC) used for statistical and government purposes that restrict the interpretation of the construction and property industry to narrow separate and distinct sectors. For example, the European, North American, and United Nations systems all define construction activity as being site based; to include trades, subcontracted labour, repairs maintenance and demolition. Whereas real estate activity is usually classified as being associated with the buying and selling of land and property so it includes: development, estate agency and management services. This is an arbitrary divide that makes the idea of a sustainable built environment no more than an allusive dream. The integral role of construction and property to the economy is overlooked and government policies designed to create change lack the necessary coherence. Consequently, there is little evidence to suggest that the complex and fragmented nature of these two sectors will allow real progress towards sustainability until they are conceived and managed as one.

REFERENCES

Carassus, J (Ed.) (2004) The construction sector system approach: an international framework. *CIB paper 293*. Rotterdam: International Council for Research and Innovation in Building and Construction.

Carillion Plc (2006) *2005 Sustainability report*. Available online: http://www.carillionplc.com/sustainability/sustainability_reports.asp

Casella Stanger (2002) *Sustainability accounting in the construction industry.* London: CIRIA publishing services

Cerin, P (2002) Communication in corporate environmental reports. *Corporate Social Responsibility and Environmental Management*, **9**, 46–66.

Companies House (2007) *DVD ROM Directory*. Cardiff: Companies House

DTi (2006) *Construction Statistics Annual Report*, *2006 Edition*. London: TSO,

Dulaimi, M S, Ling F Y Y and Ofori, G (2001) *Building a world class construction industry: motivators and enablers*. Singapore: Singapore University Press.

Elkington, J (1994) Towards the sustainable corporation: win–win–win business strategies for sustainable development. *California Management Review*, **36**(2).

Fairclough, J (2002*) Rethinking construction innovation and research: a review of government R&D policies and practices*. London: Department of Trade and Industry.

Friedman, M (1962) *Capitalism and Freedom*. Chicago: University of Chicago Press.

FTSE (2006) *FTSE4Good Index Series: Inclusion Criteria*. London: Financial Times.

Gann, D (2000) *Building innovation: complex constructs in a changing world*. London: Thomas Telford.

Hancock, J (2005) *Investing in corporate social responsibility: a guide to best practice, business planning and UK's leading companies.* London & Sterling, VA: Kogan Page

Henriques, A and Richardson, J (2004) *The triple bottom line: does it all add up?* UK and USA: Earthscan.

Ive, G and Gruneberg, S (2000) *The economics of the modern construction sector.* London: Macmillan.

Myers, D (2004) *Construction economics – a new approach.* UK & USA: Spon Press.

Myers, D (2005) A review of construction companies' attitudes to sustainability. *Construction Management and Economics*, **23**, 781–5.

Pearce, D (2003) *The social and economic value of construction: the construction industry's contribution to sustainable development.* London: nCRISP.

SCTG - Sustainable Construction Task Group (2001) *Reputation, risk and reward: the business case for sustainability in the UK property sector*. Watford: BRE.

Skanska (2006) *Skanska annual report 2005*. Sweden: Skanska AB.

Stern, N (2007) *The economics of climate change: the Stern review*. Cambridge: Cambridge University Press.

Sustainability and UNEP (2000) *Global reporters: an international benchmark of corporate sustainability reporting*. London: Sustainability.

Sustainability and UNEP (2002) *Trust us: the global reporters 2002 survey*. London: Sustainability.

Sustainability, UNEP and Standard & Poor's (2004) *Risk and opportunity: best practice in non financial reporting*. London: Sustainability.

Sustainability, UNEP and Standard & Poor's (2006) *Tomorrow's value: the global reporters 2006 survey of corporate sustainability reporting.* London: Sustainability.

WCED – World Commission on Environment and Development (1987) *Our common future.* Oxford: Oxford University Press.

WWF – World Wildlife Fund – (2004) *Building towards sustainability: performance and progress among the UK's leading housebuilders.* London: WWF and Insight Investment.

A BASIX TOOL FOR ENVIRONMENTAL ASSESSMENT OF RESIDENTIAL BUILDINGS – AN AUSTRALIAN APPROACH

Grace K C Ding and Goran Runeson

School of the Built Environment, University of Technology, Sydney, PO Box 123, Broadway, NSW 2007, Australia

The rapidly growing population in New South Wales (NSW) is the driving force behind the growth in new housing. The environmental impact in terms of land use, energy and resource consumption will significantly impede the supply of new housing. In NSW, sustainable housing has become an important focus of the government's housing policy. In response to the need for sustainable housing, the government launched a sustainability assessment tool called BASIX in July 2004 to assess and establish indoor thermal comfort, water and energy efficiency targets, and sustainability levels. The introduction of BASIX has had a profound impact on the construction industry. In order to ascertain the extent of impact, an online survey was conducted among construction professionals in NSW in March 2006. The tool has played a significant role in providing a general guideline for the sustainability performance of proposed developments. It serves as a means to make people think about water and energy saving initiatives, and to encourage good design practice without excessive additions to the cost of a new building. However, there is the opinion that there is more to be done such as control of waste and energy usage in the manufacturing of building materials.

Keywords: sustainability, performance evaluation, environmental impact, sustainable building.

INTRODUCTION

Global economic growth has increased the overall demand on energy and other resources. Unless the demand reduces significantly, resource scarcity will become a major issue in the international market and a major threat to the survival of the planet (IEA 2006). In response to the global environmental problems, the Kyoto Agreement was signed in 1990. The agreement requires countries to reduce greenhouse emissions by an average of 5% below their 1990 levels from 2008 to 2012 (McGovern 2006).

Buildings are major contributors to the environmental deteriorations and are uncaring to the environment (Levin 1997; Kein *et al*. 1999). Buildings consume approximately 30%, 10% and 40% respectively of the world's resources, water and energy (OECD 2003). Indeed, the construction and property industries have significant irreversible impacts on the environment across a broad spectrum of off-site, on-site and operational activities that alter the ecological integrity (Uher 1999). Sustainable housing has found its place in the construction industry. Local and international authorities have put environmental issues of housing development high on their agenda. The European Union will implement stricter regulations as well as financial incentives to promote sustainability in the housing sector. In other regions, similar initiatives have been introduced (IEA 2006).

The population in Australia is predicted to rise from 20 million in 2005 to 25 million in 2021 (Australia Bureau of Statistics 2005), and continue to create demand for new housing. According to the Department of Infrastructure, Planning and Natural Resources (DIPNR), currently a new dwelling is built every 14 minutes in the state of New South Wales (NSW). The increasing demand for new dwellings will no doubt increase the effect on the environment and sustainable housing has become a main focus of the government's housing policy (DIPNR 2004a). In terms of sustainability and environmental performance, these new houses were no different from houses built in the previous decade. In response to the need for sustainable housing, the NSW government therefore launched a sustainability assessment tool called BASIX in July 2004 to assess and establish indoor thermal comfort, water and energy efficiency targets and sustainability levels.

This paper provides an overview of the importance of sustainable housing in NSW and discusses the introduction of BASIX as the first government-implemented environmental assessment tool in Australia. This paper is based on an online questionnaire survey undertaken in March 2006 in NSW. The survey reviews the impact of BASIX in the construction industry since its introduction in July 2004. This paper also discusses the principles of BASIX, its implementation and its affect on sustainable housing in NSW.

BASIX – THE SUSTAINABILITY ASSESSMENT TOOL

Definition of sustainable housing

In recent years, a growing number of sustainable housing projects have been completed and sustainable construction is increasingly becoming part of the common building practice. Sustainable housing was one of the issues addressed in the United Nations Conference on Environment and Development at the Earth Summit in Rio de Janeiro in 1992 (Li and Shen 2002). Bhatti (2001) states that sustainable housing can make major contributions towards our environmental future. The methods by which housing is produced, consumed and managed, and the way it contributes to social and cultural life, have major impacts on the environment.

The issue of how housing can be made more sustainable has become a main focus of the government in Australia in relation to minimizing adverse effects on the natural environment (Gurran 2003; Department of Planning 2005). The purpose of sustainable housing is to raise the standard of living and to offer an opportunity for people to have a decent home, to enhance social unity, well being, economic growth and social improvement without adverse environmental impacts. Sustainable housing affects not only the fabric of buildings but also the social and environmental context of construction practices.

Due to population growth, the houses constructed during the next 15 years will form a considerable part of the future housing stock and there is therefore an important opportunity to improve the environmental performance of housing. Conventional housing construction has a far higher environmental impact than have new methods. Housing development is just as important as any other type of construction. The environmental impact of an individual house may be minimal but the construction of all houses together will make a significant impact on the environment. Continuous improvements are required to reduce the environmental impact of housing.

There is an increasing recognition that buildings cannot be designed without consideration for social impact (Cole 1999). Sustainable housing construction, as defined by Klunder (2004), reduces the environmental impacts of material use, energy and water consumption during the whole service life of the building. IEA (2006) further discusses how sustainable housing can be achieved in three main aspects:

- Low impact – preservation of global environment.
- High contact – harmony between the house and the environment.
- Health and amenity – health and pleasant living.

From this viewpoint, a sustainable house is characterized by futurity and equity issues which aims to ensure that everyone today and the generations to come have a decent place to live and one that is cheaper to run than most existing homes. In addition to considering land use, orientation, shadows and light, our concerns need to focus on the long-term costs: social, environmental and economic. Environmental impact depends on the population size, the average prosperity per person, and the environmental impact per unit of prosperity (Klunder 2004). In sustainable housing construction, the concept of eco-efficiency is important and implies that a reduction in the environmental impact of housing construction can be undone by trends such as an increase in the average size of houses, or a decrease in the average number of persons per house (Ding 2004; Klunder 2004).

Sustainable housing will be a growing part of the housing industry, making it a business opportunity waiting to be explored. There are multiple advantages to sustainable housing. Sustainable housing directly brings energy cost savings to owners. The lower energy consumption during the operating period contributes significantly to saving energy bills in the long run and will further save energy cost if energy prices continue to increase in the future. According to DIPNR (2004b), for the first 10 years after the introduction of BASIX, there will be accumulative saving of 9.5 million tonnes of greenhouse gas emissions, which is equivalent to removing 2.6 million cars from the roads. As compared to conventional housing, energy saving for sustainable housing can be as high as 75% with a payback period within two years (IEA 2006).

Other non-energy benefits include better indoor air quality, more marketability, reducing global warming and better living quality. Based on research in New Zealand and the USA in 2004, the non-energy benefits are more than twice as much as the energy savings (IEA 2006). Sustainable housing helps to address more directly social, economic and ecological realities. They also help to set up benchmarks for future projects as examples of best practice by moving into a social and ecological market of housing (Crabtree 2005).

Significance of BASIX in sustainability assessment of housings

Local governments in NSW have advocated sustainability in housing development for a long time (Department of Planning 2002). However, each local authority has its own environmental assessment measures in local planning tools, which vary greatly across the state. Some local authorities may be more pro-active than others, while some are still struggling to develop a single tool. The inconsistencies have caused frustration within the construction industry.

The rapid population growth in NSW has caused increasing demand for new dwellings with significant impact on water and energy consumption (Standing Committee on Public Works 2004). Design characteristics of individual homes can have a dramatic effect on the environment as well as water and energy use. For new homes, local government can specify design features including the use of insulated roof and external walls, sun shading and energy efficiency designs via its development approval powers (Department of Planning 2002).

BASIX was developed in response to the need for local governments to address these issues. BASIX was the first integrated web-based sustainability planning and assessment tool (http://www.sustainability.nsw.gov.au for full details on the BASIX assessment for new buildings as well as additions and alterations.). It was developed by DIPNR in consultation with industry and councils and is now a mandatory component of the development approval process in NSW under the Environmental Planning and Assessment Act 1979, through the Environmental Planning and Assessment Regulation 2004 and State Environmental Planning Policy.

BASIX is designed to provide a systematic assessment of the sustainability components of residential development, including regional sensitivity where appropriate and as a means of raising the awareness of sustainability in construction (Department of Planning 2002). BASIX measures energy efficiency in homes along with measuring other sustainability factors such as water usage and thermal comfort. BASIX assists councils, architects, builders and developers to standardize development practices in areas such as water, energy and land use. BASIX simplifies and improves the planning process and provides an easy and effective tool to enhance better sustainability outcomes in residential development. It also assesses the potential performance of residential developments against a range of sustainability indices. (In order to complete an assessment, log on to BASIX website at www.sustainability.nsw.gov.au and the website provides details of the proposed development as prompted by the BASIX tool. The project is assessed against the existing average and given a score. The project must demonstrate a reduction of 40% mains water and 40% energy to qualify for a BASIX certificate.)

It was first introduced in July 2004 with the aim to reduce water consumption by dwellings by 40% and energy use by 25%. In July 2005, it was applied to all new residential developments in NSW including new houses, dual occupancy and apartment buildings. In July 2006, BASIX has increased the energy reduction target to 40% and since October 2006 BASIX has become mandatory to alterations and additions to residential development across NSW.

SUSTAINABLE HOUSING – ASSESSING THE IMPACT OF BASIX

Research method

BASIX has been a mandatory requirement for development approval for all residential projects in NSW for over two years and yet no attempts have been made to ascertain its impact in the construction industry. In order to examine the impact of BASIX in promoting sustainability in residential developments, an online questionnaire survey was undertaken to investigate its role and impact. The survey was designed and distributed online so that it could obtain a wider coverage and provide a quick and easy platform for the return of the completed survey. The purposes of the survey were to examine the level of acceptance of BASIX since its introduction in July 2004 and to explore the role of BASIX in the construction industry in enhancing sustainability in residential developments. The survey also assesses the impact of its implementation as mandatory to development application for residential projects.

The questionnaire was divided into three parts. The first part was intended to obtain general details of the respondents and contains four questions. Information about the demographics of respondents and details of their professions and organizations are the main outcomes of this part. Part two was intended to obtain the viewpoint of respondents in respect to their understanding and acceptance of the tool, and it contains nine questions. The questions were designed as a standard Likert scale where respondents were asked to rate each questions from low to high or from strongly disagree to strongly agree. Part three contained 16 questions and was designed to identify the level of expertise the respondents have in the operation of the tool. The questions in this part were also on a standard Likert scale similar to the questions in Part two.

The online survey was assisted by the Association of Building Sustainability Assessors (ABSA) and Timber Development Association (TDA) in distributing the survey to their members. The anonymous questionnaire was sent to ABSA and TDA as well as to 85 practitioners in the construction industry in NSW via email with a URL containing the online survey in March 2006. Many participants also forwarded it to URLs of other practitioners in the industry. Therefore it was difficult to determine the exact response rate. At the end of May, 120 completed questionnaires had been received via online.

Observations and analysis

Generally

Of the 120 returned surveys, 80% were from male respondents. Although females are seriously under-represented, this is not surprising as construction has always been a male dominated field. Therefore, the survey results may predominantly represent opinions from male building professional but this should not have a significant impact on the outcomes. Approximately 40% of the participants have over 10 years work experience.

Respondents came from a variety of background. The design consultants and sustainability assessors contributed 56% and 24% respectively of the total returned questionnaires whilst the remaining 21% of the respondents were distributed amongst contractors/sub-contractors, project managers, developers and others. The sustainability assessors comprise of 89% of BASIX assessors and 11% of the energy assessment assessors. The design consultants are the main users for the tool and the participation of BASIX assessors can offer important feedback and opinions on the impact of BASIX in the construction industry due to their knowledge and expertise in the tool.

Approximately 85% have used BASIX before and 15% have not used it so far. Of the 85%, approximately 62% have used BASIX up to 15 times since its introduction, 11% between 15 to 35 times and 27% have used it more than 35 times. Approximately 46% of the respondents found out about BASIX from its website and 21% from BASIX consultants, 20% from company internal information and 13% from local councils. The BASIX website has fulfilled its original purpose in promoting the tool and providing information for its application.

The use of BASIX in the construction industry

Since the introduction of BASIX in July 2004, there have been substantial discussions about increased construction cost and time for development approval. However, the impact is yet to be ascertained. On one hand the mandatory use of BASIX in the development application process has created a new role of BASIX assessors and it will be one of the fastest developing services in NSW and may be throughout Australia in the near future. On the other hand, the design consultants and developers have been busy learning to use BASIX as it was designed for self-assessment on the internet.

Part two and three of the online survey were designed to obtain opinions and feedback from professionals in the industry with regards to the introduction of BASIX and the results are summarized in Table 1. The questions were designed using a standard Likert scale from strongly disagree to strongly agree.

Table 1: Summary of impact of BASIX in the construction industry

Proposition	Responses (%)				
	Strongly Disagree	**Disagree**	**No Opinion**	**Agree**	**Strongly Agree**
Online assessment tool is user friendly	6	21	13	55	6
Online help note is useful	3	13	14	58	12
BASIX helpline is useful	8	9	33	42	8
The resources on the BASIX website are sufficient	11	31	18	38	2
The 40% water target is achievable	8	15	7	58	11
The 25% energy target is achievable	3	14	3	64	16
The thermal comfort target is achievable	7	19	7	57	11
BASIX can help to provide better sustainability outcomes in residential development	12	10	6	56	16
BASIX has increased the overall construction cost	2	8	6	37	48
BASIX has increased the overall time for development application	2	20	36	27	15
BASIX should be applied to other types of construction	22	20	11	32	15
BASIX should be applied throughout Australia	17	8	19	37	19

Based on the returned surveys, the professionals in the construction industry are generally well aware of the importance of BASIX in the development of residential projects. The survey results indicate that 47% of the respondents (not including BASIX assessors) undertook BASIX assessment for the projects themselves, 15% engaged BASIX consultants and 13% used both. The results indicated that BASIX have been widely used by practitioners in the industry and has been successful for its ultimate purpose of self-assessment. Making the tool accessible via the internet has been successful and widely accepted. People can access the site anywhere in the world at any time at no cost. It is not like other energy assessment tools such as NatHERS that requires an accredited assessor and constant updates. The free access and self-assessment are the main features of BASIX that have contributed to the success of its implementation.

BASIX is regarded as user friendly and the resources are sufficient either on the online help notes or the helpline (see Table 1). Approximately 47% of the users that had assessed their projects themselves without engaging a consultant found the structure of the tool clear and 61% found it user friendly. However, some respondents consider the tool too simple and insufficient to capture sufficient sustainability issues.

With regards to the online resources, 70% and 50% found the online help notes and the helpline respectively useful in answering queries on the assessment tool (see Table 1). The helpline is arranged to provide support when needed but only 50% agree that the helpline has provided sufficient support to the use of the tool. Relating to the resources on the website, 40% agree that the resources on the website were sufficient whilst 42% disagree (see Table 1). However, there is no indication to the type of resources that are missing from the website.

With regards to assessment criteria, 72% believe that BASIX can help to provide better sustainability outcomes in residential developments (see Table 1). The majority of respondents found the assessment criteria of thermal comfort, a 40% reduction in water and 25% reduction in energy consumption achievable (see Table 1). After the survey was completed, in July 2006, the energy target was increased to 40%. There is no information as yet about whether the new target of 40% reduction in energy consumption is achievable and further investigation in this area will be undertaken later. Some respondents worry that they may struggle to achieve the 40% energy saving targets. Others also suggest that embodied energy needs to be addressed in the manufacturing process of building materials and components as well as the on-site process.

As discussed earlier BASIX has impacted on the overall construction cost as additional elements such as sun shadings, insulations to walls and ceilings, water tanks for recycling storm water and so on are required in order to satisfy the requirements. With reference to Table 1, approximately 85% of the respondents agree that the implementation of BASIX has increased the overall construction cost of residential developments by about 10%, which is different from the DIPNR report of BASIX-compliance cost of 3–4% (BMT & Assoc 2005). The economic savings may take a few years to come to fruition and this is why this system is not popular with developers. Only 42% of the respondents agree that BASIX has increased the overall time for development application approvals (see Table 1). They suggest that the time required for approval has increased by about 10%.

With reference to Table 1 only 47% of the respondents agree that BASIX should be applied to other types of construction and 56% agree that BASIX should be applied throughout Australia. However, many believe that the tool needs further development to improve it usefulness. Thermal comfort is one of the variables that are assessed within the BASIX programme. It addresses insulation, heat transfer through glazing, shading and active heating and cooling. There is a field of thought in the industry that this section should have given attention to the thermal mass, which also has a major effect on the indoor environment of a dwelling. In their opinion, the thermal comfort section of BASIX is not a true representation of the actual thermal properties of the building and an accredited assessor may be required in this respect.

SUMMARY AND CONCLUSION

Construction is one of the largest users of environmental resources and one of the largest polluters of the man-made and natural environment. The improvement in the performance of buildings with regards to the environment will indeed encourage greater environmental responsibility and place greater value on the welfare of future generations. There is no doubt that BASIX contributes significantly to achieving the goal of sustainable development within construction. On one hand, it provides a methodological framework to measure and monitor environmental performance of residential development, whilst on the other it alerts the building profession to the importance of sustainable development.

Sustainable housing is multidimensional and the evaluation of sustainable housing cannot be achieved using a single criterion and single objective function. The decision-making process for sustainable housing uses multiple criteria and objectives and needs to be considered on a whole-of-life approach as it is not just considering economic and environmental problems. It also needs to include social and economic evaluations during the service life of the building. Therefore, a set of multiple goals and criteria needs to be considered simultaneously. The sustainable housing industry needs to appreciate the affordability for homebuyers especially those issues relating to design and cost. The reality is that homebuyers will respond to environmental issues providing it is affordable and does not come at a cost penalty compared with houses that deliver inferior environmental performance. Professional designers should maximize the environmental performance and concentrate more on achieving lower costs. If additional cost items are to be included, developers, builders and governments will need to consider introducing innovative financial incentives.

The accessibility of the tool via internet and free access are the main reasons for the success of the tool. It was generally accepted that the tool has played a significant role in providing a general guideline to the sustainability performance of a proposed development. It is a start but there is more to be realized. The key benefit of the tool is that it leads to better thermal comfort to users and to reduced water and energy consumption as well as less greenhouse gases emission. However, there is also the opinion that there is more to be done such as control of waste and energy usage at manufacturing of building materials for future development of the tool to be used in other types of construction. It serves as a means to make people think about water and energy saving initiatives and to encourage good design practice without excessive additions to the cost of a new building.

Irrespective of the advantages and disadvantages that the BASIX system may have, it has come into effect quite smoothly and with continued improvement and updating, it could become one of the most important planning and design tools in the construction industry. There may currently be shortfalls in the system and eventually they will be rectified, but the point is that new residential dwellings will have less environmental impact than their predecessors will. A step forward is better than standing still.

REFERENCES

Australian Bureau of Statistics (2005) *Population projection, Australia, Catalogue No. 3222.* Canberra: Australian Government Publishing Service.

Bhatti, M (2001) Housing/futures? The challenge from environmentalism. *Housing Studies*, **16**(1), 39–52.

BMT & Assoc (2005) *Indicative elemental estimate–Multi-unit residential development–BASIX analysis*. NSW: Department of Infrastructure, Planning and Natural Resources.

Cole, R J (1999) Building environmental assessment methods: clarifying intentions. *Building Research and Information*, **27**(4/5), 230–46.

Crabtree, L (2005) Sustainable housing development in urban Australia: exploring obstacles to and opportunities for ecocity efforts. *Australian Geographer*, **36**(3), 333–50.

Department of Planning (2002) *Partnering BASIX with Local Government*. NSW: Department of Planning.

Department of Planning (2005) C*ity of cities - A plan for Sydney's future*. NSW: Department of Planning. Available online: http://www.metrostrategy.nsw.gov.au/

Ding, G K C (2004) The development of a multi-criteria approach for the measurement of sustainable performance of housing projects. *In:* O Ural, A Frattari and E R Albatici (Eds.) *32nd IAHS World Congress: Sustainability of the Housing Projects*, 21–5 September 2004, University of Trento, Italy.

DIPNR (2004a) *More sustainable homes in NSW*. NSW: Department of Infrastructure, Planning and Natural Resources.

DIPNR (2004b) *Summary of cost benefit study for BASIX*. NSW: Department of Infrastructure, Planning and Natural Resources.

Gurran, N (2003) *Housing policy & sustainable urban development: evaluation the use of local housing strategies in Queensland, New South Wales and Victoria*. NSW: Australia Housing Urban Research Institute.

International Energy Agency (IEA) (2006) *Business opportunities in sustainable housing: A marketing guide based on experiences from 10 countries*. New Zealand: BRANZ.

Kein, A T T, Ofori, G and Briffett, C (1999) ISO 14000: its relevance to the construction industry of Singapore and its potential as the next industry milestone. *Construction Management and Economics*, **17**, 449–61.

Klunder, G (2004) The search for the most eco-efficient strategies for sustainable housing construction: Dutch lessons. *Journal of Housing and the Built Environment*, **19**, 111–26.

Levin, H (1997) Systematic evaluation and assessment of building environmental performance (SEABEP). *In: Second International Conference, Building and the Environment*, June, Paris, 3–10.

Li, H and Shen, Q (2002) Supporting the decision-making process for sustainable housing. *Construction Management and Economics*, **20**, 387–90.

McGovern, J P (2006) *Global warming earth summit fact sheet*. Centre for Environmental and Regulatory Affair of the National Centre for Public Policy Research, Washington. Available online: http//www.nationalcentre.org/KyotoFactSheet.html (accessed 5 January 2006).

OECD (2003) *Environmental sustainable buildings: challenges and policies*. OECD report.

Standing Committee on Public Works (2004) *Inquiry into energy consumption in residential buildings, Report No. 53/02*. NSW: Legislative Assembly.

Uher, T E (1999) Absolute indicator of sustainable construction. *COBRA 1999, RICS Research Foundation*. London: RICS.

VALUE-ENGINEERING USING LINEAR PROGRAMMING: OPTIMIZING INDOOR AIR QUALITY (IAQ)

B.G. Celik,[1] K.R. Grosskopf[2], P. Oppenheim[2] and C.J. Kibert[2]

[1]*Centex Construction, 3100 McKinnon Street, Dallas, TX, 75201, USA*
[2]*Rinker School of Building Construction, University of Florida, PO Box 115703,Gainesville, FL, USA*

One of the key requirements of a high performance building is to create an efficient, healthy and comfortable indoor environment that provides measurable performance benefits. Unfortunately, traditional value engineering tools often lack the flexibility to efficiently "screen" the seemingly endless combinations of alternatives to those few that are most likely to provide the highest level of performance relative to cost. A mixed integer linear programming tool has been developed to determine optimal IAQ design parameters and equipment specifications for high performance commercial buildings. By expressing the dimensionless linear function of each benefit-cost objective and constraint in relation to one another, the linear model is capable of defining a boundary condition where the productivity benefits of added ventilation are maximized relative to added equipment and O&M costs. By applying operations research to value engineering, a mixed integer linear programming model has demonstrated the ability to select appropriate high performance technologies far more efficiently than conventional time intensive value engineering techniques, especially for those alternatives whose costs and benefits are difficult to quantitatively define.

Keywords: cost, decision analysis, life cycle, value management.

INTRODUCTION

Value is the ratio of function to cost and can be increased by either improving function relative to cost or reducing cost while maintaining function. There exists a tenet within the paradigm of value engineering that quality must not be compromised in the pursuit of value. Yet, too often, value engineering results in little more than an exercise in cost cutting and scope reduction, resulting in less than optimal building performance. One of the key requirements of a high performance building is to create an efficient, healthy and comfortable indoor environment that provides measurable performance benefits. Traditional value engineering tools often lack the flexibility to efficiently screen alternatives that are most likely to provide the highest level of project specific performance benefits from among the many that are commercially available. As a result, only a limited number of high-performance alternatives are ever considered, usually as a product of the intuition or bias of the architect or engineer. Nowhere may this condition be more evident than in the assessment of IAQ management options, where in addition to the costs associated with inefficient mechanical systems and building operations, specific levels of indoor air pollutants may adversely affect the health and comfort of workers, resulting in lost productivity, increased absenteeism and added health care costs.

[2] kgro@ufl.edu

Value-engineering (VE) was developed during World War II by the General Electric Company to retool production processes affected by shortages in labour and materials. During this time and for nearly 30 years thereafter, value was defined as the lowest unit cost of production. Although VE had migrated to transportation, building construction and other industries, the value paradigm changed little until the energy crisis of the 1970s when building owners and operators were suddenly faced with soaring operation costs, interest rates and inflation. As a result, the focus of value in the building industry began to shift away from the initial cost of production (e.g. construction) and toward the total life-cycle cost of the building. A new generation of VE methods soon emerged in an attempt to quantify the total cost of building ownership during the design phase, where design changes could be most cost effectively implemented.

Among the most widely used tools today, *life-cycle cost analysis* (LCCA) considers all significant costs of competing design alternatives and chooses the alternative that meets functional requirements at the lowest total cost of ownership. Among these traditional costs of ownership are initial design and construction costs, operations, maintenance, and repair costs, replacement costs (less residual salvage or resale values), disposal costs and financing (interest) costs. The LCCA method escalates all costs to their future year of occurrence and discounts them back to present values (Fuller 2007). The discount rate can be as low as the general rate of inflation for essential building systems or as high as the building owner's minimal acceptable rate of return (MARR) for building systems that are considered non-essential, discretionary investments. Building systems that provide essential safety or reliability functions may be selected based on lowest life-cycle cost, whereas non-essential systems must generally provide operational savings on added first-cost investment that meet or exceed the MARR or "hurdle" rate established by the building owner (Grosskopf 2006).

Yet, the definition of value continues to evolve. No longer is value defined in terms of achieving minimum performance benchmarks or functional requirements at lowest cost, but rather maximizing life-cycle productivity of the building relative to life-cycle costs. One indication of this change is the apparent shift away from lowest-bid award to negotiated "best value" delivery. In 1985, 82% of all construction projects in the US were awarded based on lowest "hard" bid, compared to less than 5% design-build delivery based on flexible design and negotiated project costs. Today, more than 50% of all construction in the US is let using the "best value" approach (Good 2006). Increasingly, building owners and operators are factoring the qualitative benefits of design, such as aesthetics, employee comfort and performance, environmental impact and historic preservation, into their definition of value. For example, worker productivity can significantly influence the economic analysis and decision-making process. Over a 30-year period, operations costs account for approximately 1–2% of the total cost of ownership, while initial building costs total 6–8%, and personnel costs total 90% or more (USDOE 1996). As a result, a 1% increase in productivity could nearly offset the building's total energy cost.

Although LCCA can be modified to account for qualitative or "soft" costs, it becomes inherently less stable as each new variable is added and as the level of uncertainty associated with each variable increases. In addition, LCCA is generally limited to evaluating individual systems under steady state conditions. As a result, mixed integer linear programming has been identified as a multivariate analysis technique that can not only evaluate multiple interdependent building systems, but also define *optimal* combinations of building systems or design parameters within a functional range of user-defined project constraints and operational conditions. Unlike traditional LCCA, linear programming does not provide a finite output, but rather identifies building systems and design parameters that fall within a feasible region where all of the dimensionless, linear functions that represent each economic and operational constraint are satisfied. The feasible region or "objective function", bounded on all sides by the project constraints, often takes the form of a two-dimensional polygon, which can be expanded or contracted based on acceptable levels of risk and uncertainty.

To demonstrate the linear programming approach to value engineering, a hypothetical case study has been developed to define optimal IAQ design parameters and select optimal IAQ equipment options for a commercial office building. IAQ options are among the most complex of building systems to value engineer since IAQ benefits often require substantial capital investment, are difficult to quantify (e.g., improved worker health and productivity, reduced absenteeism, etc.) and may result in added operations and maintenance (O&M) costs. The purpose of this research is to develop a simplified decision tool for building designers, builders, operators and owners to screen a large number of value-engineering options and design parameters to those most likely to provide the greatest level of performance benefits in relation to costs.

BACKGROUND

IAQ, along with lighting, acoustics, and vibration, are a few of many indoor environmental quality (IEQ) issues that can affect the well-being and productivity of building occupants. US Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of many pollutants are often 2–5 times higher than outdoor levels (USEPA, 1993). Indoor air pollutants are of particular concern because it is estimated that most people spend as much as 90% of their lives indoors.

Although providing a healthy indoor environment can be achieved in part by selecting appropriate interior finish materials and managing sources of indoor pollutants such as cleaning agents, process chemicals, dust, moulds, pollen, dander and smoke, HVAC systems must be designed, operated and maintained to provide adequate air ventilation and filtration. According to a US National Institute of Occupational Safety and Health (NIOSH) survey, 52 out of 100 US office buildings with IAQ problems suffered from inadequate ventilation. Building code compliant levels of indoor ventilation air and filtration in the US are largely determined by the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) Standard 62-2001. Minimum ASHRAE standards require 0.57m^3/min/person (20ft^3/min/person) of fresh air ventilation for typical office environments having on average, seven workers per 92.9m^2 (1,000ft^2) of air-conditioned floor area.

Monitoring indoor contaminants and pollutants such as $C0_2$ for example is important since studies have shown that levels of $C0_2$ above 1,000ppm can cause drowsiness and general discomfort, making it more difficult for building occupants to think and work (Bas 1993). Although efforts to identify and reduce sources of indoor pollutants are generally the most effective alternative, not all sources can be eliminated by source management. Some non-particulate contaminants are too small and the volume of re-circulating air too great to be cost-effectively filtered, absorbed or *ad*sorbed. $C0_2$, a by-product of human respiration, is a prime example. As a result, outside air (OA) ventilation in combination with source management and filtration is commonly used to dilute pollutants within the indoor air and exhaust contaminated air to the outside.

Ventilating conditioned indoor spaces with unconditioned outside air often requires additional equipment size and cost, energy consumption and maintenance. An investigation into a "typical" 10-storey office building determined that OA ventilation alone resulted in a 2.8% increase in heating energy costs and a 6.3% increase in cooling costs (Bas 1993). However, improved worker health and productivity resulting form improved indoor air quality may provide substantial payback. In 2000, three studies were conducted to determine the increase in productivity, if any, associated with added levels of OA ventilation using 90 human subjects. By doubling OA ventilation from the minimum ASHRAE standard of 20cfm to 40cfm, productivity improvements of nearly 2% were observed in test subjects performing simulated office tasks. At present, however, there exist limited tools to quickly and efficiently evaluate OA ventilation design parameters and equipment options that maximize these and other performance benefits whilst minimizing incremental equipment and O&M costs.

METHODOLOGY

To demonstrate the linear programming approach to value engineering, the model will attempt to determine the optimal rates of OA ventilation for a hypothetical commercial office building in Miami, Florida (USA). For the purposes of this study, "optimal" is defined as a rate of OA ventilation that meets or exceeds the ASHRAE 62-2001 standard of 0.57m^3 (20cfm) per building occupant and maximizes worker productivity returns on added equipment and O&M investments.

Estimating the costs of improved ventilation

The first step in assessing the costs associated with increasing the OA ventilation rate is to estimate the OA increase that will be required. The following equation presents a procedure for estimating the needed increase, assuming that dilution is the sole mechanism which reduces the contaminant concentration. It is assumed that the concentration of the contaminant of concern in the outside air is zero.

$$C = \frac{d \times (a - b)}{b}$$

where,

C = Incremental increase in outdoor airflow rate required to achieve the desired reduction in contaminant concentration (m^3)

a = Current average concentration of the contaminant of concern in the building (ppm)

b = Average concentration to which "a" should be reduced (ppm)

d = Current flow of OA into the building (m^3).

Next, the incremental increase in equipment and life-cycle O&M costs must be considered. Depending on the climate, added fresh air ventilation will generally require additional equipment capacity to condition and circulate the added volume of unconditioned outside air. The values presented in Table 1 represent the incremental increase in heating and cooling capacity required to condition each additional 28.3m^3 (1,000cfm) of outdoor air to an indoor temperature of 21°C (70°F) and 50% relative humidity for five geographic regions in the US.

Table 1: Incremental increase in heating, ventilation and air-conditioning (HVAC) capacity by geographical location (Henschel 1999)

City	Required increase in cooling capacity, 3.5kW (ton) per 28.3m^3 (1,000cfm) OA	Required increase in heating capacity, 1.0kW per 28.3m^3 (1,000cfm) OA
Chicago	3.3	22
Miami	4.6	6
Minneapolis	2.7	26
Washington, DC	3.9	16
Seattle	0.5	13

To provide the added heating and cooling capacity needed to condition the added OA ventilation, the existing HVAC system design must either be modified (enlarged) or a dedicated OA ventilation and conditioning system must be installed. The values presented in Table 2 represent the incremental increase in installed HVAC system equipment costs per incremental increase in resistance (strip) heating and air-to-air direct expansion (DX) cooling capacity for new construction (not retrofit).

Table 2: Incremental increase in heating and cooling equipment costs for modified HVAC systems and dedicated OA systems (USEPA 2005)

System	Cooling capacity range, kW	Heating capacity range, kW	Incremental cost, $US/kW
Central HVAC system	0–70		355
	>70		318
		0–10	95
		11–20	75
		21–40	50
		41–100	30
		>100	18
Dedicated OA system	0–18		426
	>18		355
		0–10	125
		11–20	80
		21–40	50
		41–100	30
		>100	18

To determine the added operations costs, the incremental increase in OA ventilation is factored by the added energy necessary to condition and circulate each cubic metre of added outside air. The total number of heating and cooling degree-days is used to determine how much energy is needed to condition each cubic metre of OA ventilation. A degree-day is defined as each 24-hour period that the outside temperature is one degree above the cooling set-point (22°C) or one degree below the heating set point (12°C) within a given year. However, a calculation of energy consumption that is based only on the total heating or cooling degree-days in a specific geographical location may be misleading as the mechanical system may not be supplying OA ventilation into the building during the night, usually the coldest period of a day or during weekends and holidays. The modified energy use values (kWh/yr/m^3) presented in Table 3 assume that OA ventilation is being supplied for 13 hours per day (6:00 a.m.–7:00 p.m.) and 5 days per week for the specified US locations.

Table 3: Incremental increase in annual heating and cooling energy use per unit increase in OA ventilation rate by geographical location (Henschel 1999)

City	Increase in cooling energy use, kWh (3,413Btuh) per m^3 (28.3cfm) OA	Increase in heating energy use, kWh (3,413Btuh) per m^3 (28.3cfm) OA
Chicago	107.8	340.0
Miami	555.6	1.7
Minneapolis	107.8	522.4
Washington, DC	165.8	207.3
Seattle	24.9	232.2

By factoring the annual energy required to condition each unit of OA ventilation in each geographic region by the total incremental increase in OA ventilation required, the total increase in energy consumption (kWh/yr) can be determined. For electric cooling systems using direct expansion (DX) of a refrigerant, the efficiency of the cooling system must be considered. The efficiency of the cooling system, commonly referred to as the coefficient of performance (COP), calculates the amount of heat transfer output for each unit of electric energy input. A COP of 2.9 for example, means that the cooling system can remove 2.9W (10Btu) of heat within the building for every 1W of electric input energy. The efficiency of electric heating systems using resistance coils is approximately 0.9. The efficiency of gas or fuel oil heating systems is approximately 0.85.

In most cases, marginally increasing the capacity of an existing HVAC system to accommodate added OA ventilation will not substantially increase maintenance costs. However, if additional intake or exhaust fans are required or if dedicated OA units are added to the original design, maintenance labour costs can be expected to increase. Each additional intake or exhaust fan will on average, require an additional 5 hours of maintenance labour per year. Dedicated OA units will require 20 hours of maintenance labour per year.

Most buildings are financed by bonds, bank loans or venture capital. Consequently, the cost of the construction, including the cost of OA ventilation equipment, is usually amortized over the service life of the equipment, usually 10–20 years. Depending on the interest rate at which funds are burrowed (*i*) and the amortization period (*n*), a capital cost recovery factor (*CRF*) can be used to annualize the added cost of OA ventilation equipment.

$$CRF = [i(1+i)^n]/[(1+i)^n - 1]$$

The *CRF* can be multiplied by the total added equipment cost to determine the annualized installed cost of the equipment. Combined with the added operations and maintenance cost, if any, a total annualized cost for added OA ventilation can be determined.

Estimating the benefits of improved ventilation

In 2000, three studies were conducted to determine the increase in productivity, if any, associated with added levels of OA ventilation using 90 human subjects. By increasing OA ventilation from 0.60m^3 to 5.05m^3 while holding all other indoor climate conditions constant, the subjects' performance of simulated office tasks were observed. Results found that doubling OA ventilation can initially increase overall performance by 1.8%. However, the rate of increase in performance benefits declines with respect to additional increases in OA ventilation beyond approximately 1.56m^3.

In fact, as presented in Table 4, increasing OA ventilation another five-fold to 5.05m^3 results in only another 1.9% increase in worker productivity (Wargocki 2000).

Table 4: OA ventilation rate (m^3/min/person) vs. worker performance index (Wargocki 2000)

OA (m^3)	PI	OA (m^3)	PI	OA (m^3)	PI	OA (m^3)	PI	OA (m^3)	PI
0.60	0.9900	1.56	1.0220	2.51	1.0289	3.46	1.0330	4.42	1.0358
0.71	1.0000	1.67	1.0230	2.62	1.0294	3.57	1.0333	4.52	1.0361
0.81	1.0069	1.77	1.0240	2.72	1.0300	3.67	1.0337	4.63	1.0364
0.92	1.0110	1.87	1.0249	2.83	1.0305	3.78	1.0340	4.73	1.0366
1.03	1.0139	1.98	1.0257	2.93	1.0309	3.89	1.0344	4.84	1.0369
1.13	1.0161	2.08	1.0264	3.04	1.0314	3.99	1.0347	4.95	1.0371
1.24	1.0179	2.19	1.0271	3.15	1.0318	4.10	1.0350	5.05	1.0374
1.34	1.0195	2.30	1.0277	3.25	1.0322	4.21	1.0353		
1.45	1.0208	2.40	1.0283	3.36	1.0326	4.31	1.0356		

Using the Wargocki data, the incremental performance benefit or performance index (PI) of each added cubic metre of OA ventilation can be determined by multiplying the worker's fully burdened labour rate or salary by PI minus one. This value (PI-1.0) represents the incremental performance "profit" index (PPI). For instance, if the average cost of the employee to the employer is $US 30,000 per year, then increasing the employee performance index to 1.02 could improve the value of productivity $US 600 per year per employee. By multiplying the average benefit per employee by the total number of employees, a total annualized benefit for added OA ventilation can be determined. If the total annualized benefit for added OA ventilation is greater that the total annualized cost, then a positive return on investment can be realized.

Benefit-cost optimization using mixed integer linear programming

To simplify the relationships of two or more non-linear functions, such as the relationship between OA ventilation and worker performance, linearization tools can be used. One such tool, *piece-wise* linearization, divides non-linear functions into linear segments. A decision can be made to either "segment" underneath the curve and thus, underestimate values or segment above the curve and overestimate values. Also, the greater the number of linear segments used to represent the a non-linear function, the greater the accuracy. The slope of each linear segment (m) can be calculated by finding the tangent of the angle (θ).

$$\mathrm{Tan}(\theta) = \frac{(\text{Max PPI - Min PPI})}{(\text{Max OA - Min OA})} = m$$

By applying the point-slope method $y = mx + c$, the relationship of the performance profit index (PPI) and OA ventilation can be linearized. In other words, performance profit index values (y) can be approximated for each linear segment by factoring the segment slope (m) by corresponding rates of OA ventilation (x) in cubic metres per person.

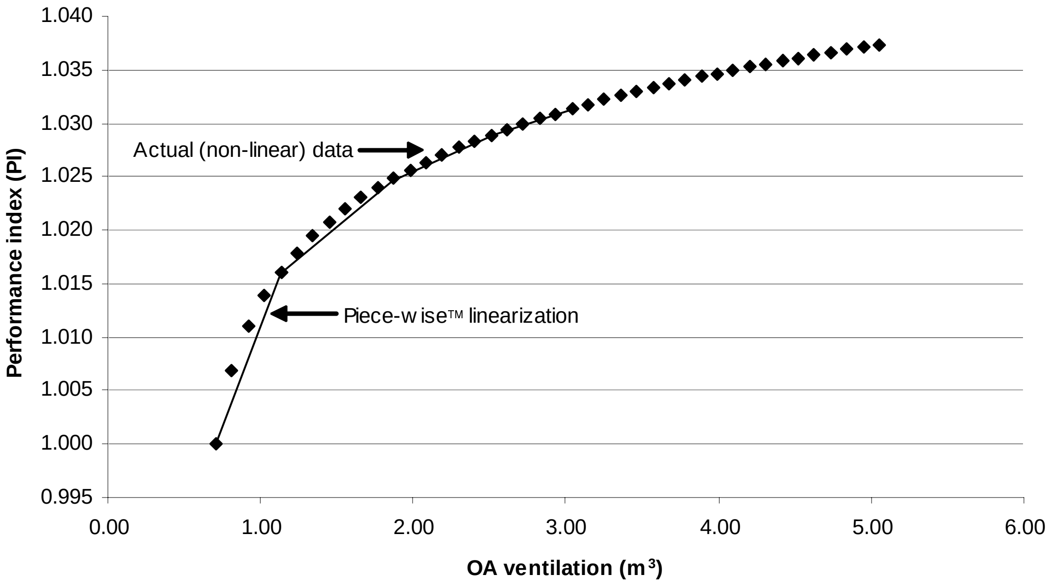


Figure 1: Linearization of OA ventilation rate (m^3/min/person) vs. worker performance index

Having expressed all incremental equipment costs and performance benefits as linear functions, a mixed integer linear expression (e.g. *objective function*) can be derived to determine the optimal rate of OA ventilation.

$$\text{Min}\, z = \sum_{i=1}^{2} (A_i X_i Y_i) - W$$

where,

z = Total annual benefit (or cost) of the incremental OA ventilation system ($US)

A_1 = Variable cost of air by central unit ($US/person/$m^3$)

A_2 = Variable cost of air by dedicated unit ($US/person/$m^3$)

X_1 = Amount of OA supplied by a central unit (m^3/person)

X_2 = Amount of OA supplied by a dedicated unit (m^3/person)

Y_1 = "1" if central unit is used, "0" if not

Y_2 = "1" if dedicated unit is used, "0" if not

W = Profit generated by increased productivity by using PPI function ($US).

Constraints

$X_1 + X_2 \geq 20\text{cfm}; \leq 140\text{cfm}$

Requires that the total amount of added OA ventilation supplied by enlarged central unit(s) or dedicated unit(s) should be at least 20cfm per person and the amount of OA does not exceed 140cfm since the Wargocki study finds little or no increase in performance for OA ventilation above 140cfm.

$Y_1 + Y_2 = 1$

Requires the selection of at least one or a combination of both, enlarged central or dedicated HVAC systems.

$X_1 - 140Y_1 \leq 0$

Requires that X_1 (added ventilation air from enlarged central unit) will be zero if Y_1 (enlarged central unit) is equal to zero (not used).

$X_2 - 140Y_2 \leq 0$

Requires that X_2 (added ventilation air from dedicated unit) will be zero if Y_2 (dedicated unit) is equal to zero (not used).

RESULTS

Case study office building

A 670m^2 (7,200sf) office building in Miami, Florida (USA) with 50 employees requires 0.57m^3/min (20cfm) per person of outside air ventilation or 28.3m^3/min (1,000cfm) total to adhere to the ASHRAE 62-2001 standard. The average cost of the each office worker to the employer is $US 20,000. As a result, the employer incurs approximately $US 1,000,000 in fully burdened labour expenses (salaries, payroll taxes, fringe benefits, etc.) each year. Using the values presented in Tables 1–4, and the incremental cost assumptions below, the *objective function* determines that the optimal rate of outside air ventilation is 1.25m^3/min/person or 62.5m^3/min total, achieved by modifying (enlarging) the design capacity of the existing, central HVAC system prior to construction.

- Interest rate (*i*) = 8% APR.
- Service life (*n*) = 15 years.
- Cooling efficiency = 2.9 (DX).
- Heating efficiency = 0.9 (electric strip heat).
- Electric rate = $US 0.09/kWh.

The *ratio* of total annualized performance benefits ($US 21,972) in relation to total annualized performance costs ($1,672) is maximized at 1.25m^3/min/person (44cfm/person) OA ventilation. However, the model indicates that the *net* benefit of added OA ventilation continues to increase well beyond 2.83m^3/min/person (100cfm/person). Again, the optimal rate of OA ventilation is highly dependent on a number of independent variables and functions. As electric rates approach $US 0.12/kWh for example, the optimal rate of OA ventilation drops to 1.08m^3/min/person (38cfm/person) whilst holding all other variables constant.

In summary, the following research has demonstrated that optimizing indoor air quality through outside air ventilation is at least dependent on the following primary variables:

- Number of employees.
- Outside air ventilation requirements.
- Added capacity of HVAC equipment per climate.
- Added installed cost of HVAC equipment per location.
- Energy efficiency of HVAC equipment.
- Added energy use of HVAC equipment per climate.
- Added energy operations cost of HVAC equipment per location.

- Added maintenance cost of HVAC equipment per location.
- Improved performance index.
- Total annualized installation, operations and maintenance cost.
- Average annual salary of the employees.

CONCLUSIONS

One of the key requirements of a high performance building is to create an efficient, healthy and comfortable indoor environment that provides measurable performance benefits. Yet studies of human exposure to air pollutants indicate that indoor levels of many pollutants in the US are often 2–5 times higher than outdoor levels, resulting in worker discomfort, potential health risks and loss of productivity. Unfortunately, IAQ improvements are among the most complex of building systems to value engineer since IAQ benefits often require substantial capital investment and may actually result in added operations and maintenance (O&M) costs. The reductions in “soft costs” such as reduced absenteeism and health care costs, as well as gains in worker comfort and productivity, are difficult to quantify.

As shown, nearly a dozen independent variables may influence the design of an optimal ventilation system alone. By applying a linear programming approach to value engineering, the annualized costs and performance benefits of added outside air ventilation have been successfully transformed into linear functions using “piece-wise” linearization. A mixed integer model was then developed to determine the optimal rate of outside air ventilation, as well as the type of equipment that will most cost effectively provide the optimal level of ventilation in terms of benefit-cost ratio. As shown, the primary advantage of the linear programming method is the speed and simplicity of the solution generation and the potential of the mixed integer model to value engineer optimal combinations of integrated IAQ solutions (e.g. ventilation, filtration, source management, etc.) as well as other building design elements.

REFERENCES

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (1992) Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter Standard 52.1-1992. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc: Atlanta, GA.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) (2004) Ventilation for Acceptable Indoor Air Quality, Standard 62-2004. American Society of Heating, Refrigeration, and Air Conditioning Engineers: Atlanta, GA.

Bas, E (1993) *Indoor Air Quality in the Building Environment*. Troy, MI: Business News Publishing Company.

Fuller, S (2007) *Life-Cycle Cost Analysis (LCCA)*. Gaithersburg, MD: National Institute of Standards and Technology (NIST).

Good, T (2006) *Trends in Project Delivery - Engineering New Record (ENR)*. The Haskell Company. M.E. Rinker Sr. School of Building Construction, University of Florida. Gainesville, FL.

Grosskopf, K R and Kibert, C J (2006) Economic Incentive Framework for Sustainable Energy Use in US Residential Construction. *Construction Management and Economics*, **24**(8), 839–46.

Henschel, D B (1999) *A Preliminary Methodology for Evaluating Cost-Effectiveness of Alternative Indoor Air Quality Approaches*. Washington, DC: US Environmental Protection Agency, EPA/600/R-99/053.

United States Department of Energy (USDOE) (1996) *Sustainable Building Technical Manual: Green Building Design, Construction and Operations*. Washington, DC: Office of Building Technologies.

United States Environmental Protection Agency (USEPA) (1991) *Building Air Quality: A Guide for Building Owners and Facility Managers*. Available online: http://www.epa.gov/iaq/largebldgs/baqtoc.html (accessed 3 March 2005).

United States Environmental Protection Agency (USEPA) (1993) *Targeting Indoor Air Pollution: EPA's Approach and Progress*. EPA Office of Air and Radiation. Available online: http://www.epa.gov/iaq/pubs/targetng.html (accessed 3 March 2005).

United States Environmental Protection Agency (USEPA) (2005) *EPA Green Indoor Environments Program*. Available online: http://www.epa.gov/iaq/greenbuilding (accessed 3 March 2005).

United States Environmental Protection Agency (USEPA) (2005) *IAQ Tools for Schools Kit – IAQ Coordinator's Guide*. Available online: http://www.epa.gov/iaq/schools/tfs/guide5.html (accessed 25 February 2005).

United States Environmental Protection Agency (USEPA) (2005) *Indoor Air Quality for Schools*. Available online: http://www.epa.gov/iaq/schools/tfs/pdf_files/reference_guide.pdf (accessed 16 June 2006).

Wargocki, P, Wyon, D P and Fanger, P O (2000) Productivity is affected by the Air Quality in Offices. *Healthy Buildings*, **1**, 635–40.

VIRTUAL FRAMEWORK FOR PROJECT MANAGEMENT EDUCATION – EXPERIENCES FROM TEACHING-LEARNING PERSPECTIVE

Hemanta Doloi[1]

Faculty of Architecture, Building and Planning, University of Melbourne, Victoria 3010, Australia

This research presents a self-learning model, to ensure participants address and meet project challenges with their inherent professional and managerial skills. Flexible delivery and self-learning mechanisms have proven to be one of the best learning approaches among professional project managers within dynamic corporations. The model facilitates project management education at a higher level than commonly available. Progressive learning and competency development for effective utilization of project management knowledge and methodologies has been redesigned to match the needs of the future. Research-based, team-learning exercises, coupled with peer-assessing and self-learning exercises have facilitated such development, within a controlled learning process. This distinct learning mechanism aims to educate professional project managers, at a superior level, across various project management disciplines, while referencing to the global competency frameworks from major professional bodies. The outcomes and validity of the pedagogy have been demonstrated using a hypothetical case study.

Keywords: education, future studies, globalization, project management.

INTRODUCTION

The continuous development of the multifaceted character of the project management (PM) profession has increasingly been a focus of attention over the past few decades. Project managers are responsible for the overall control of projects and are concerned with delivering on time, within budget and to the appropriate quality (Manivong *et al*. 2004). Organizations in many industry sectors are moving away from traditional forms of management towards a more project-oriented culture. This requires a combination of technical interpersonal skills for managing projects in diverse contexts (Marton and Saljo 1976; Dooley *et al.* 2005).

While continuous development in the PM profession is on the increase, the relevant educational model with appropriate delivery strategies becomes the point of major concern among the higher education industries (Munns 2001). Recently, many universities have been trying to adopt a distance educational model using an online delivery platform. The US set the trend in the early 1990s that resulted in a mass education system being born (Manivong and Doloi 2004). The trend was primarily caused by the birth of distance learning programmes and institutions and the needs of individuals for higher degrees to keep pace with the dynamic corporate culture.

Traditional delivery practices in the classroom environment do not provide sufficient flexibility in terms of time and locations for global audiences (Nunan 1994). Such

[1] hdoloi@unimelb.edu.au

factors predominately must have been contributing to education sectors becoming adaptive to terms such as globalization, internet technology, virtual conferencing systems, cultural empathy, international workforce, and so on. Emeritus Professor Wells (1998) asked critical social questions about the current direction of universities: ‘how are we going to manage higher education, maintain standards, be innovative and serve the students?’. He also raises the question of how the so-called ‘emerging nations’ are going to provide the educational infrastructure for their growing middle classes in a way which will satisfy the rapidly increasing demands. Another aspect of such movement is the ever-increasing pressure on university funding (Doloi and Stevens 2004). Western governments have had continuing political debates on their roles in developing and funding universities. For example, currently in Australia, the federal government has enforced a policy on reducing higher education funding and increased places for full fee paying students (Davis 2005).

RESEARCH HYPOTHESES AND ADOPTED METHODOLOY

Today’s higher education providers are seen to be a more strategic venture where multi-disciplinary dependencies contribute to the fulfilment of strategic objectives of the entire educational system (Munns 2001; Williams 2003; Manivong and Doloi 2004). In current educational practices, the challenging complexities of an institution are typically due to the following reasons:

- the presence of uncertainty and risks affecting virtually all aspects of knowledge creation, delivery and operations;
- multifaceted curriculum requirements and associated functional integration;
- complex and changing business environments with highly networked stakeholders;
- multiple choices, change of priorities and global audiences with free market ventures;
- global competition, internationalization and competitive market demand.

Given the profound changes in educational environments and the increasing evidence of the shift of current practices, this paper seeks to address the following research questions:

- How does the diversity and complexity of today’s practices impact on establishing next generation educational delivery platform?
- How can the advancement of information technology (IT) and information services (IS) be used for the strategic existence of an educational organization?
- Will the framework be seen as a core capability in delivering required competency in project management education and supporting the flexibility, reflectivity and adaptability across the global boundary?
- How will the delivery of knowledge be relevant to ensure diagnostic cross-communication between current industry practices and educational institutions?

Focusing on the above questions, this research aimed to define an advanced online delivery framework and underlying strategies in a proactive and explicit manner. Results of the market research conducted at the University of Melbourne has shown that there is a need for innovative design and flexible delivery of professional courses for busy corporate professionals to keep pace with business dynamics and progressive competency development in their areas of expertise (QBrand Consulting 2005). The research investigates the robustness of using an Internet-based platform as core functionality for designing and delivering a course targeting global audiences. A case study is used to demonstrate how the framework has been used to effectively deliver the knowledge and ensure the appropriate practice-based educational outcomes in a virtual learning environment.

COMPETENCY-BASED LEARNING AND HIGHER EDUCATION

An effective learning environment relies on the competencies of those who are going to use such education in practice. Regardless of infrastructure and other associated delivery factors, the competency framework is the key to delivering practical knowledge in the higher education sector (Williams 2003; Crawford 2004; Morris 2004). Figure 1 shows a high level competency development framework integrating environments and associated business roles.

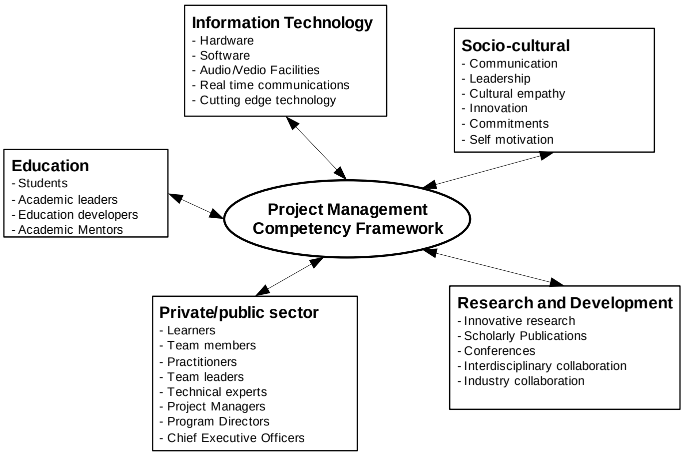


Figure 1: Competency development framework

As seen, the framework comprising practice roles and competencies associated with the educational model must be designed thoughtfully with full understanding of curriculum objectives and technological balance. While discussing competency-based education, the underlying characteristics associated with the term ‘competency’ must be understood. These characteristics lie mainly among the people and their behaviour or thinking patterns across any situation over a reasonable time period (Saba and Shearer 1994). The term ‘competency’ usually refers to the skills, knowledge, personal characteristics and behaviours needed to effectively perform a role in an organization in order to contribute to meeting the strategic business objectives (Roschelle and Teasley 1995).

There is an essential need for educators to clearly understand the related roles and competencies for professionals in applied fields (Crawford 2004). The development of educational models especially for the distance delivery model must integrate the roles of key stakeholders or target audiences with their business roles and responsibilities facilitated by the emerging pedagogy and technology. As shown in Figure 1, five major drivers such as education, information technology, socio-cultural aspects, research and development and private/public sector business practices have been integrated in developing the competency framework in the model. In the flexible delivery model, competency-based learning plays a great role in realizing an appropriate educational outcomes.

THE VIRTUAL PEDAGOGY MODEL

Figure 2 shows the pedagogical model of the distance learning framework. The model has been developed by integrating the views of a number of stakeholders from the teaching and leaning points of view, such as students, tutors, course advisers and course designers.

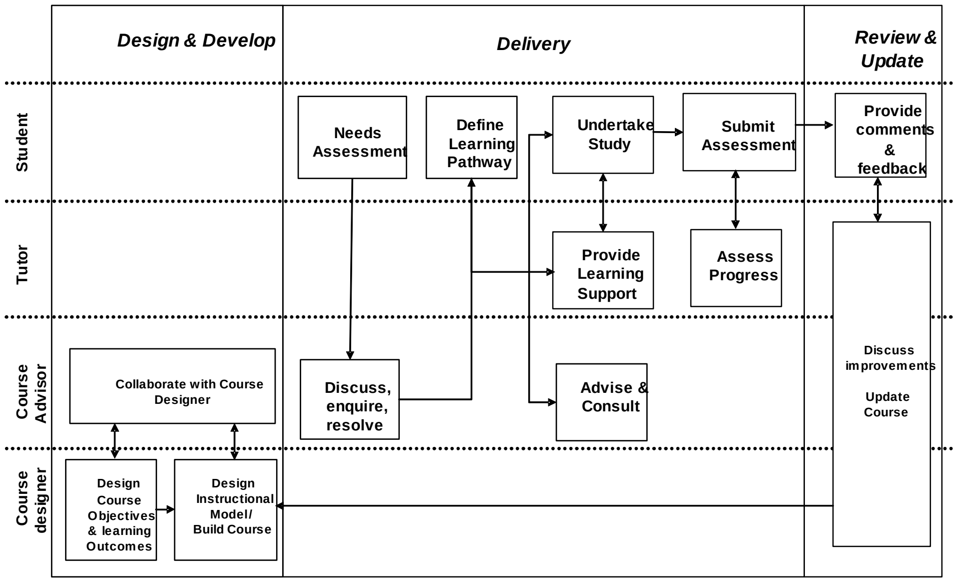


Figure 2: The pedagogical model

The overall model comprises three major phases: Design and Development, Delivery and Review and Updates. The Design and Development phase focuses on design and staged delivery of the module-specific technical contents. In a typical module, closed interaction is required between the course adviser and the course designer or content provider for the seamless integration of the technical contents within the target competency framework.

The focus of the Delivery phase is on the student's learning where actual learning takes place through rigorous interaction within the structured learning programme and learning pathways, assisted by the course adviser as well as the respective tutors. The computer-based self-assessment toolkit allows students to assess their strengths and weaknesses against given target outcomes. A customized learning programme and the specified learning pathways ensure progressive development through a peer feedback mechanism within the team-learning environment.

In the Review and Update phase, all the stakeholders interact closely in reviewing and providing feedback for continuous updates. Self- and peer-reflection reports are the key to achieving target outcomes in this process. Moreover, such dynamic interaction and continuous reflection allow for the integration of student feedback for further model enhancement.

MODEL FRAMEWORK

Figure 3 shows a high level framework of the model. As seen, there is an entry level compulsory module followed by a few performance parameters, such as understanding of the professional strength, gap analysis and progressive development towards meeting a specific target outcome at the end.

The entry level module, 'Project Management Framework', allows students with cognate as well as non-cognate professional backgrounds to develop an understanding of the global standards of the project management competency framework (Crawford 2004; Project Management Institute 2004).

A computer-based in-house self-assessment toolkit facilitates students' self-assessment of their generic and technical strengths. A notional professional development plan then allows the students to evaluate knowledge and competency gaps and benchmark the self-learning and progressive development curves towards the target competencies. The target competency may vary from student to student and depends on the relevant business roles of a given organization (Figure 2). The overall competency matrices have been developed based on the organizational and project management competency standards set by the leading professional associations (e.g. Project Management Institute, International Project Management Association, Australian Project Management Association, etc.) (Crawford 2004).

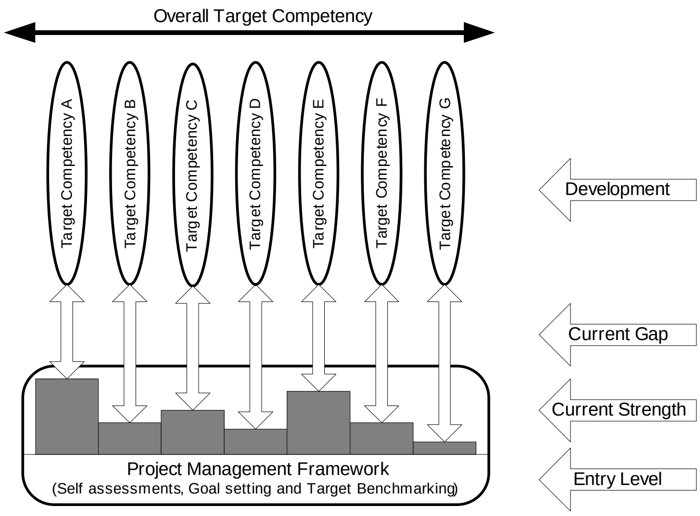


Figure 3: Broad architecture of the framework

LEARNING PATHWAYS AND SYSTEM CAPABILITY

The overall model facilitates dynamic interaction and communication where learning takes place. A typical module aims to capture all the learning and teaching components from the students' perspectives. Some of the key features of a typical module are discussed below:

- *Introduction* – outlines the profiles of the module's educators and available teaching assistance, if any. This section also provides a brief on what to expect in the course module, any textbooks, and special requirements, e.g. a spreadsheet program.
- *Assessment* – outlines the academic assessment criteria and the assessment structure of the course module. A major assessment component is the participation rate of students within the virtual team learning environment facilitated by the system.
- *Activities* – depicts the learning activities and tasks that need to be conducted by students or groups to gain academic credit. Typically three to six assignments are given in any course module. The learning activities are

typically threefold: start-up exercise, case-based application and individual reflection and demonstration. The start-up exercise is designed for students to expedite learning of the fundamental knowledge. The case-based application allows students to apply the fundamental knowledge to devise an appropriate solution to their own case projects. Individual reflection and demonstration allows students to demonstrate their progression and achievements in a personalized, guided environment. Each assignment has guidelines and relevant learning notes which can be downloaded.

- *E-library* – for students to conduct further research and information gathering which may or may not be relevant to the subject matter. Students are able to access all documents provided by this service.
- *Submission* – allows students to upload and submit their assignments online to educators for assessments.
- *Discussion forum* – allows students and educators to interact by posting public or private messages with attachments to other colleagues in the module or for a particular group.
- *Team/group evaluation* – this feature allows confidential assessments to be made between students in a group. The submitted report allows educators to individualize students' marks from the group study.
- *Teaching assistant assessment* – this feature allows educators/teaching assistants to mark and upload detailed comments to students. Marks are not finalized until the end of semester examiners meeting.
- *Team/group discussion forums* – for educators to create groups or teams of students and create private discussion forums for every group in the class.
- *My transcripts* – allows students to download and print their current academic transcripts.
- *Audio-conferencing system* – allows for synchronous virtual communication between teaching teams and students to conduct regular discussion sessions throughout the academic semester.

As can be seen from the above sample of a typical online course, it is obvious that a dedicated online system is required to deliver the embodied education/training philosophies. Since one of the main goals of virtual delivery is to extend education globally, and reach out to untapped world markets, it is prudent for these education systems to be accessible over the Internet. Today the Internet offers a very cost-effective solution to online education delivery. All types of media (e.g. word processing documents, video clips, picture files, sound files, etc.) can be transmitted, viewed, edited and played over Internet.

APPLICATION OF THE MODEL

As mentioned earlier, this model has been designed based on the author's experience with delivery of online education over a number of years. Though no systematic documentation or recording was taken during the time, observations and experience have provided the following proven successful teaching and delivery approaches:

- *Group learning and independent learning* – Group/team learning provided a means for students to learn more effectively resulting in a network of cooperation and collaboration. Independent learning proved effective where educators did not provide a 'cookbook' approach to learning. As it was a graduate level programme the key was to provide challenging tasks for different minds and to perhaps change old mindsets via challenging tasks.

- *Competency-based learning* – Proved successful in this type of management programme. A 'hands-on' application of PM theory to workplace integration proved effective. Just relying on a 'body of knowledge' was not good enough. Rather, it was the exchange of information, concepts, ideologies, and so on that were more important.
- *Educator responsiveness and feedback* – Since students came from all corners of the world it was imperative that students receive feedback on questions they posted and more importantly receive assignment feedback rapidly. Since the Internet and computers are what students physically interact with and see, it was imperative that communication would occur through the system's email and discussion forum without relying on external means, which was efficient and spontaneous.
- *Real-time (audio/video) conferencing* – To counteract the asynchronous mode of interaction, a dedicated audio/video conferencing system was useful for students to get together to work on real-time tasks. This system is also useful for live seminars or lectures if students need it.
- *Focus on asynchronous delivery* – Because of student time commitment to family and work, asynchronous learning was the most effective means to deliver this type of online education. It was also more cost-effective. Studying at your 'own pace' proved to be what students wanted.

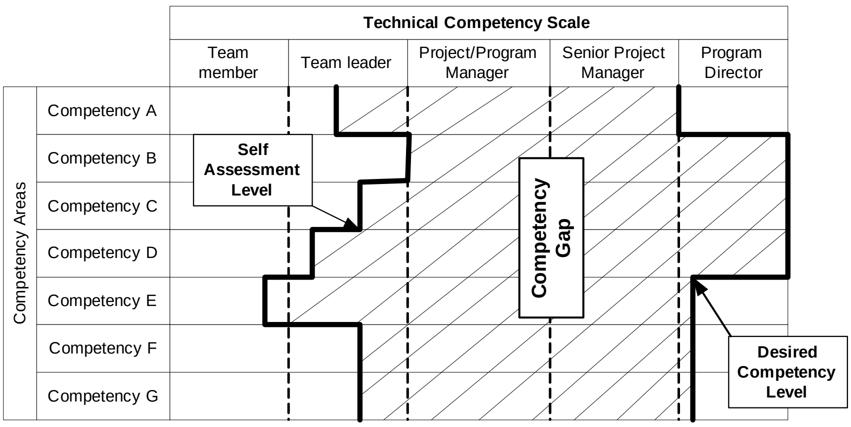


Figure 4: Goal-setting framework

The case study showed that success of an online programme can be attributed to the delivery mode and design of a self-driven learning programme. There is no doubt that the IT systems form an integral part of the education service and must be considered carefully before being implemented. The system itself, if not properly implemented, could 'bog down' key resources, and the focus may be turned away from delivering a quality education in the process.

Figure 4 shows an outcome of a goal-setting exercise that students need to perform before entering any formal module. The model allows students to work through a number of project management competency matrices such as socio-cultural, technical and organizational competencies, assessing strengths and weaknesses in the area. The result of this goal-setting exercise allows students to feel the competency gap between the current and desired competency levels. The assessments are then combined to get a holistic evaluation of personal as well as professional attributes before selecting subject matter for further developments.

Such assessment exercises can be undertaken from a distance using a secured IT platform. A notional professional development plan is then developed setting up the desired competency levels across the global competency matrix and relating to the respective business roles.

CASE STUDY

Though the paper claims that competency-based education is possible by advocating an appropriate distance learning educational model, questions persist regarding the parallel evolution of related roles, a curriculum supporting the development of professional skills and finally formal degree programmes. Researchers have provided both positive and negative insights regarding competencies associated with distance learning. These discussions are important in understanding the perspectives of both emerging and new professionals in the field and provide implicit signals as to the ways in which the mature professionals can be trained. The aim of the case study is to further clarify the model in terms of distance learning roles and competencies through the exploration of a typical graduate student perspective. It is worth mentioning that the output chart provided in the paper is hypothetical because of sensitivity in publicizing the original student’s result.

Self-assessment and professional development planning

As mentioned earlier, the overall competency framework for each module comprises three broad categories of competencies relevant to the target knowledge areas of the project management profession. These are: general management, functional management and socio-cultural aspects. The general management functions are generic and focus on the generic managerial aspects in the project context. Functional management focuses mainly on the project management functions specific to the technical competencies. Socio-cultural management functions are based on soft competencies associated with project management practice.

Table 1 shows the levels of self-assessment along with the expected goals against some of the general management functions. There are six attributes against each management function showing an incremental order of 20% progression towards the completion. As can be seen, students’ competency levels at the beginning are assessed and target outcomes are set identifying the gaps for further development.

Similar outcomes of self-assessments are expected along target competencies in both project management functional and socio-cultural aspects. The outcomes of such self-assessment exercises entirely depend on students’ professional as well as relevant academic backgrounds. Targets are also set as per the personal as well as professional requirements associated with any business roles. While the learning road map may be similar across a given class size, the target achieved or reported at the end depends on students’ personal and professional judgements.

Table 1: Beginning and target competencies in general management

General Management		Learner / Understanding / Developing / Practicing / Competent / Leading (0% to 100%)	Begin	Target
Integration Management	Beginning			
	Target		20	80
Business Management	Beginning			
	Target		0	60
Procurement Management	Beginning			
	Target		40	80
Technology Management	Beginning			
	Target		20	100
Stakeholder Management	Beginning			
	Target		20	80
System Management	Beginning			
	Ending		0	60

Competency report

Table 2 shows the comparative report with the analysis of learning progression within a set boundary. As can be seen, the competency achieved (refer to the rows denoting 'ending' against each management function) is shown along with the levels at the beginning as well as targets. For instance, beginning and target competencies of a given student on technology management in the general management aspect are 20% and 100% respectively. After completion of the module, the student reports that he/she has acquired up to 40% against the target of 100%. In this case, there is a need to undertake further action in developing and closing the gap by an additional 60%. The strategy for such development is normally tracked through a professional viva presentation and final report with an idea that a solution may be devised in the model in its dynamic review process.

Table 2: Acquired competency in general management

General Management		Learner / Understanding / Developing / Practicing / Competent / Leading (0% to 100%)	Begin	End	Target
Integration Management	Beginning Ending Target		20	40	80
Business Management	Beginning Ending Target		0	60	60
Procurement Management	Beginning Ending Target		40	80	80
Technology Management	Beginning Ending Target		20	40	100
Stakeholder Management	Beginning Ending Target		20	80	80
System Management	Beginning Ending Target		0	60	60

The model advocated in the paper emphasizes heavily self- and team-learning aspects as opposed to the traditional lecture-based approach. Academic research is the key to developing the knowledge of the subject matter. Hypothetical analysis allows students to devise solutions for given problems facilitated by the educators as part of pilot exercises. Once the level of knowledge has been built up to an appropriate level, the same needs to apply on a real case project in team environment to devise the best solutions with a complete holistic approach. The required technical competencies are assumed to be achieved by such exercises throughout the module. Similarly, socio-cultural competency is developed through mechanisms such as peer discussion, group discussion and self-reflection.

CONCLUSION

This paper highlighted the fact that true educational outcomes experience in traditional teaching model can well be replaced with appropriate pedagogy for flexible delivery. The rapid growth of virtual/online programmes has changed the way education is being taught and delivered. The validity of research-based pedagogical development is becoming important in the value addition process of the delivery of knowledge to the wider community. This is because of increased demand for continuous professional development to gain competitive advantage in the corporate business environment. A model has been developed and validated as a major tool to exploit a virtual teaching philosophy and delivery strategy using online platforms. A pedagogical approach of flexible delivery of academic project management education has been demonstrated. The model is purely competency based with appropriate reference to leading project management bodies across the globe and has proved to be quite successful integrating educational principles and industry practices within the project management profession.

REFERENCES

Crawford, L (2004) Global body of project management knowledge and standards. *In*: P W G Morris and J K Pinto (Eds.) *The Wiley guide to managing projects*. Hoboken, NJ: John Wiley & Sons.

Davis, G (2005) Growing esteem – choices for the University of Melbourne. Discussion Paper, The University of Melbourne, Australia.

Doloi, H and Stevens, C (2004) Global learning framework – paradigm shift in project management education. *In*: *Proceedings of 2nd International Conference on Project Management, ProMAC2004*, 12–14 October, Tokyo Bay Area, Nakase 2-1, Mihama-Ku, Chiba City, 261-0023 Japan, 143–9.

Dooley, K E, Linder, J R and Dooley, L M (2005) *Advanced methods in distance education*. Hershey, PA: Information Science Publishing.

Manivong, K and Doloi, H (2004) A web-based education system for successful delivery of online project management programs. *In*: *Proceedings of 2nd International Conference on Project Management*, ProMAC2004, 12–14 October, Tokyo Bay Area, Nakase 2-1, Mihama-Ku, Chiba City, 261-0023 Japan, 510–17.

Manivong, K, Wei, C and Doloi, H (2004) The need for a knowledge management framework for project-based organizations: conceptualizing a project knowledge management system. *In*: *Proceedings of 2nd International Conference on Project Management*, ProMAC2004, 12–14, October, Tokyo Bay Area, Nakase 2-1, Mihama-Ku, Chiba City, 261-0023 Japan, 84–92.

Marton, F and Saljo, R (1976) On qualitative differences in learning 1: outcome and process. *British Journal of Education Psychology*, **46**, 4–11.

Morris, P (2004) The validity of knowledge in project management and the challenge of learning and competency development. *In*: P W G Morris and J K Pinto (Eds.) *The Wiley guide to managing projects*. Hoboken, NJ: John Wiley & Sons.

Munns, A K (2001) Engineering students using project management to manage learning. *Project Management Journal*, **32**(4), 18–23.

Nunan, T (1994) The role of distance education in mass higher education. Paper presented at the International Conference for Distance Education: Distance Education: Windows on the Failure, The Correspondence School, Willington, NZ.

Project Management Institute (2004) *A guide to the project management body of knowledge* (PMBOK). Newtown Square, PA: Project Management Institute.

QBrand Consulting (2005) *Project 17UM, A report on quantitative research into a proposed new postgraduate course on project management*, Project Management Graduate Programme, The University of Sydney, Australia, available at http://www.pmgp.usyd.edu.au.

Roschelle, J and Teasley, S D (1995) The construction of shared knowledge in collaborative problem solving. *In*: C O'Malley (Ed.) *Computer supported collaborative learning*. Berlin: Springer.

Saba, F and Shearer, R L (1994) Verifying key theoretical concepts in a dynamic model of distance education. *American Journal of Distance Education*, **8**(1), 36–59.

Wells, M (1998) A virtual campus requires more than technology. Paper presented at SEARCC'98 South East Asia Regional Computer Confederation, 7–10 July 1998, Darwin, Northern Territory, Australia.

Williams, P E (2003) Roles and competencies for distance education programs in higher education institutions. *American Journal of Distance Education*, **17**(1), 45–57.

MANAGEMENT AND ECONOMICS EDUCATIONAL PROGRAMMES AS A CONSTRUCTION INDUSTRY DEVELOPMENT SUPPORT

Zoran Cekic[1]

Department of Construction Management, Union University Faculty of Construction Management, Sarajevska 20, Belgrade, Serbia 11000

Considering the latest dynamical changes in knowledge and technologies it is very important for higher educational institutions to develop and implement a strategy for the continuous enhancement of quality of their programmes and awards, supported by the results of educational research projects. Educational programme integrated database and knowledge base is suggested as an IT support for programme development, monitoring and renewal. In order to become a mirror industry image educational programmes have to respond to industry requirements for broader construction management and economics competencies. The Delphi method is applied to find which competencies industry experts consider most important for competitiveness and industry development. Needs for project management competencies are based on the traditional industry belief that successful project execution is the fundamental key to corporate success. Requirements for specific business and economics knowledge and skills are based on the belief that management education is a critical issue for sustainable long-term corporate success and industry development. Construction management and economics knowledge and skills are very important for integrated innovation processes in construction companies and could foster organizational improvement and sustainable industry development.

Keywords: education, industry development, knowledge-based systems.

INTRODUCTION

In the near future great investment activity is planned in South-East Europe. Many large construction projects are now funded by international financial institutions and private investors, and constructed and supervised by international companies. That is why engineers employed in construction companies need additional knowledge and skills in project and corporate management to successfully manage complex construction projects with short duration and strict quality requirements. In this dynamic situation it is clear that construction companies are strongly oriented towards employing educated, skilled and experienced engineers.

In order to develop and implement a strategy for the continuous enhancement of the quality of their programmes and awards, an educational research project *Construction Management and Economics Education Programmes as a Construction Industry Development Support* is organized in cooperation with the Faculty of Construction Management, Union University, Belgrade, the Higher School of Civil Engineering and Geodesy, Belgrade, and the Association of Civil Engineers, as a professional institution at a national level. Construction management and economics (CME) educational programmes in these institutions, with some

[1] cekicz@eunet.yu

similarities and differences, were specially designed and adapted to the construction industry's specific needs. At the beginning of this research, which is scheduled from September 2006 to May 2008, the Delphi method is applied to find which competencies (learning outcomes of formal, non-formal and informal education process) industry experts consider most important for construction companies' competitiveness and industry development.

An important research phase is development and implementation of an integrated education programme database and education programme knowledge base, as an IT support for education programme development, monitoring and renewal.

The next generation of civil engineering professionals is similarly witnessing the emergence of knowledge-based tasks as a central focus of organization operations (Chinowsky and Guensler 1998; Drucker 1993). The industry is slowly adopting the concept of learning organizations (Cayes 1998), and still has not come any closer to arriving at a consensus on education requirements appropriate for new managerial challenges (Chinowski 2000). The challenge to organization leaders is to develop knowledge dissemination mechanisms that retain a focus on individual enhancement while enhancing distribution to the overall organization (Stata 1989).

It is very important for higher educational institutions to carefully examine the educational needs and opportunities within construction companies and set the education objectives required to create an innovation corporate culture and civil engineering learning organization. The new civil engineers combine university education with professional experience and are entering the engineering industry with a broader educational perspective that includes influences from economics, marketing, management and computing (Grant 1996).

In an attempt to respond to industry requirements for specific educational skills, university programmes have slowly emerged as a mirror image of the construction industry (Long 1997; Singh 1992; Lowe 1991; Wadlim 1985; Hancher 1985; Grinter 1955). University programmes have followed project management tradition as they have prepared each succeeding generation of industry managers (Oglesby 1990; Betts and Wood-Harper 1994). According to the results of many studies in this field (Chinowsky and Paul 1997; National Academy of Sciences 1995; National Science Foundation 1996), management education is a critical issue for the long-term success of the civil engineering industry.

EDUCATIONAL PROGRAMME QUALITY ENHANCEMENT STRATEGY RESEARCH

If Europe is to achieve its aspiration to be the most dramatic and knowledge-based economy in the world (Lisbon strategy), then European higher education will need to demonstrate a policy and associated procedures for the assurance of the quality and standards of their programmes and awards. In order to develop a quality enhancement strategy and formal mechanism for the approval, periodic review and monitoring of higher educational programmes and awards, educational research is based on the following framework:

- Definition and analyses of all phases of CME education programme life cycle.
- Industry influence in education programmes development, monitoring and renewal.
- System for regular industry feedback (cyclical monitoring and periodic review by employers, labour representatives and professional organizations) of competencies and learning outcomes of CME department graduates.
- Development of education programmes information system (IS) which can be considered as an IT support in programme development, monitoring and renewal.

- Data and information from all phases of the education programme life cycle could be stored in an integrated educational programme database (IEPDB).
- IEPDB could form a construction industry education programmes knowledge base, as a subsystem of a construction industry knowledge base.
- An education programmes knowledge base could be used in programmes development.
- It is possible to apply principles of lifelong learning (LLL) in the field of CME.
- Development and dissemination of CME knowledge and skills could foster innovation in corporate culture, integrated innovation processes and organizational improvement.
- Managing the integrated innovation processes could foster industry development.

External quality assurance of institutions and programmes should be undertaken on a cyclical basis. The life cycle of the education programme is shown in Figure 1.

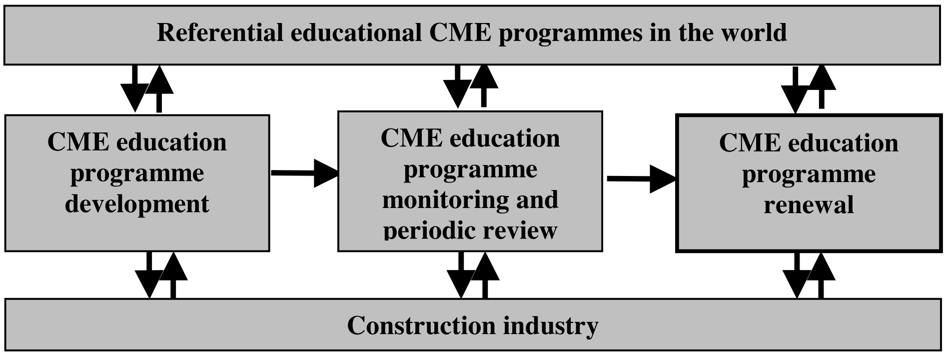


Figure 1: Life-cycle of CME education programme

The confidence of students in higher education is more likely to be established and maintained through effective quality assurance activities which ensure that programmes are well designed, regularly monitored and periodically reviewed. Quality assurance of programmes and awards are expected to include regular feedback from employers, labour representatives and relevant organizations. Learning outcomes are sets of competencies, expressing what the student of the department will know, understand or be able to do after the completion of a process of learning, whether long or short. In the final analyses the aim of the education programme is to prepare learners for an active and positive role in the construction industry (DGEC 2005).

The use of learning outcomes represents a shift in thinking from a stuff-based input-oriented system to a student-centred output-oriented approach. Learning outcomes are expressed in terms of competencies. Competencies represent a dynamic combination of attributes, abilities and attitudes, and can be subject-specific or generic. Programme monitoring and periodic review is shown in Figure 2.

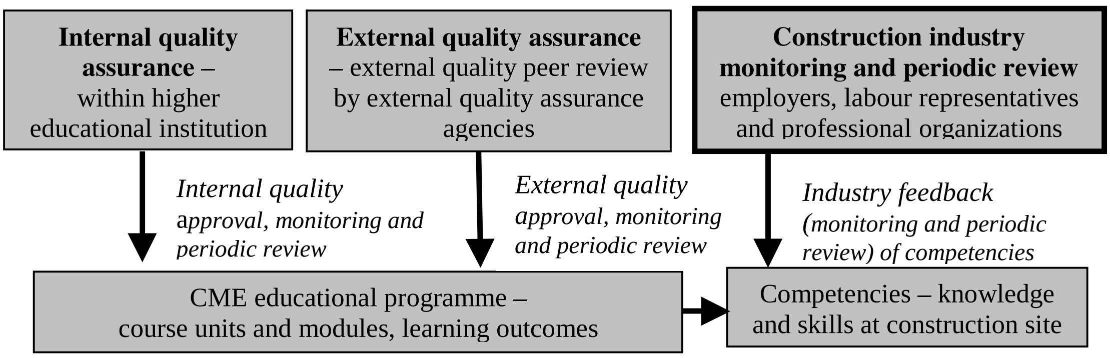


Figure 2: CME programme monitoring and periodic review

Ensuring CME educational programmes' quality assurance is not a static but a dynamic process. It should be continuous and not 'once in a lifetime'. Outcomes analysis can provide very useful information about developments, trends, good practice and areas of persistent difficulty of CME programmes and can become useful tools for quality enhancement.

IT SUPPORT IN EDUCATION PROGRAMME DEVELOPMENT, MONITORING AND RENEWAL

The higher education institutions in the field of CME should collect, analyse and use relevant information for the effective management of their programmes of study and other activities. The quality-related education programme information systems (IS) are expected to cover the institution's own key performance indicators to compare themselves with other similar organizations and to extend the range of their self-knowledge. Integrated education programme database (IEPDB) is an integrated database containing data from the design, operational and renewal phases of the education programme life cycle (Figure 3).

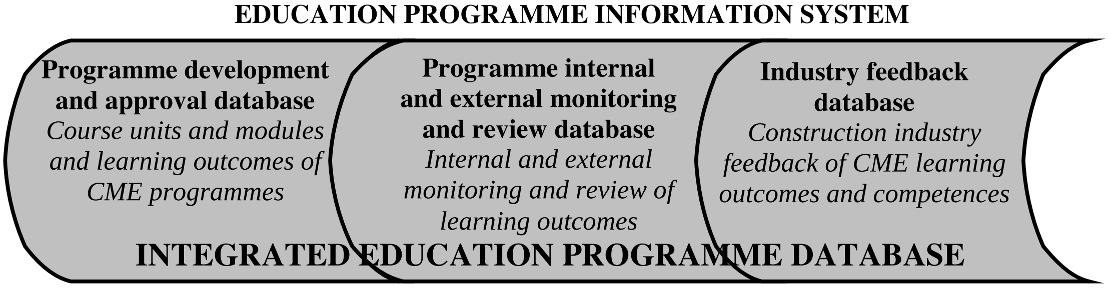


Figure 3: Integrated CME programme Database

In order to preserve, spread and manage the knowledge accumulated in previously realized CME education programmes, all IEPDB can be gathered and stored in a newly created education programmes knowledge base (EPKB). Knowledge-based systems (KBS) should preserve developed and rare knowledge in such a form that can be efficiently distributed to anyone who needs it (Dutton *et al.* 1996). EPKB, as a subsystem of the industry knowledge base, is shown in Figure 4. The education programmes information system is intended to be developed at the Faculty of Construction Management and Higher School of Civil Engineering and Geodesy, as an IT support in CME education programme development, monitoring and renewal. EPKB is intended to be developed at the Association of Civil Engineers, as a longstanding national professional organization.

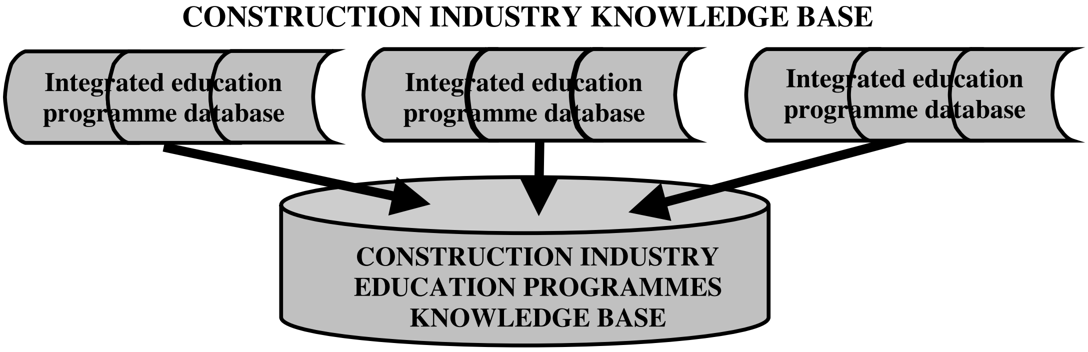


Figure 4: Construction industry education programmes knowledge base

LIFELONG LEARNING, INTEGRATED INNOVATION PROCESSES AND INDUSTRY DEVELOPMENT

The successful construction companies are increasingly facing the need to establish lifelong learning – LLL as a centrepiece of strategic management. Updating core engineering knowledge or expanding skills to areas such as management and technology, education is the emerging avenue to organization improvement (Chinowski 2000).

LLL comprises all types of learning and training within any type of institution or company, or outside in the field, i.e. formal, non-formal and informal learning. Where formal learning takes place in CME education and training institutions and leads to recognized CME diplomas and other types of documented qualifications, non-formal learning occurs outside mainstream education and training and does aim at formalized certificates. Informal learning is a natural consequence of everyday life. CME lifelong learning as an organization improvement and industry development support is shown in Figure 5.

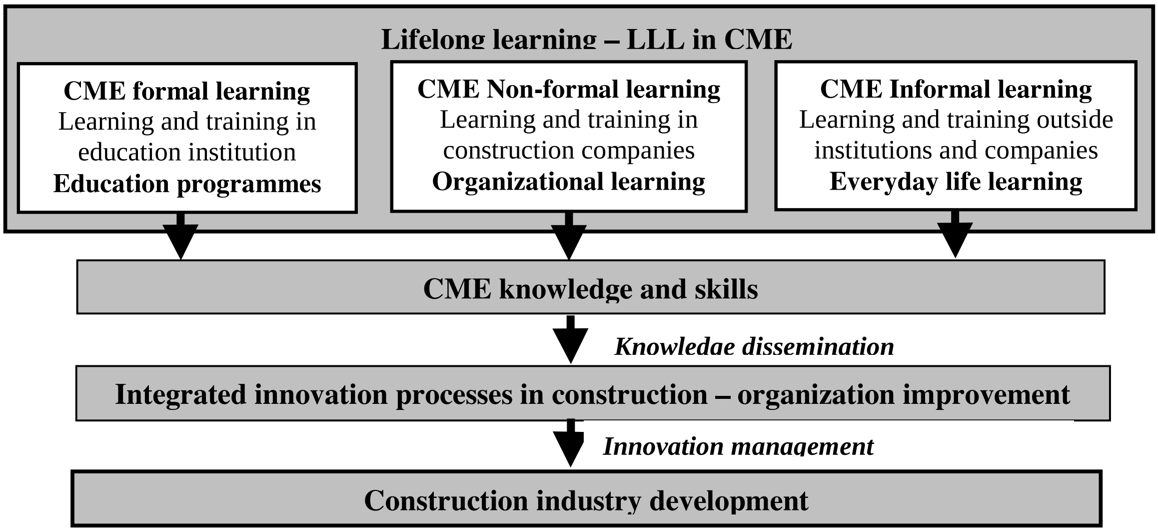


Figure 5: LLL as a support for organizational improvement and industry development

Construction companies face many challenges owing to the changed technical, economic and social conditions inside and outside the sector. Raised environmental demands can be identified as challenges for a change. As soon as such a change is an economically successful novelty for the company, it can be considered to be an innovation. However, in order to innovate successfully, it is necessary to create efficient innovation processes. Organizational learning (OL) is one of the mechanisms that facilitate innovation.

The chief aim of innovations is to contribute to meeting the needs of the clients, providing for the quality of the services offered and gaining advantages in competition. Using the available knowledge is one of the main components of the innovative strategy. It is possible to group justification for lifelong education of civil engineering organizations into four categories (Chinowski 2000): bridging the management knowledge, enhancing career advancement opportunities, enhancing personnel and professional development and ensuring competency in discipline knowledge. With the focus on long-term benefit, a strong organization knowledge base is a foundation to retain competitive advantages.

RESEARCH METHOD AND METHODOLOGY

The main goal of the first part of educational research is to find which CME competencies (as a learning outcome of education process) leading construction companies in the market consider most important for competitiveness and future industry development. The need to introduce new education opportunities to address emerging business environments is a significant challenge. Once an organization establishes the need for a professional education programme, the next issue that arises is what topics should be studied. This research explores the essential CME knowledge and skills that the successful project and corporate manager in the industry should possess.

The result of Delphi surveys is a statistically significant consensus about necessary CME knowledge and skills. Delphi is an iterative forecasting procedure characterized by three features (Chan *et al.* 2001): anonymity; iteration with controlled feedback; and statistical response. The iterative nature of the procedure generates new information for panellists in each round, enabling them to modify their assessments and project them beyond their own subjective opinions (Corotis *et al.* 1981). The success of the Delphi method depends principally on careful selection of the panel (Edmunds 1999). The Delphi method adopted in this research consisted of four rounds (from September 2006 to January 2007).

RESEARCH RESULTS

Ten panel members represent a wide distribution of top managers from internationally successful Serbian companies, providing a balanced view for the Delphi survey. In the first round of Delphi, experts were asked to provide at least five competencies they considered important for projects and corporate success. In the second round experts were asked to indicate the relative importance using a simple three-level scale: very important, important and not important. Competencies that attracted 50%, or below, in the category of ‘very important’ or ‘important’ were removed. As a result, only 12 (of 17) were included in the round 3 study (Table 1).

In round 3, experts were asked to enter a utility factor against each competence. A utility factor is a factor to indicate the degree of suitability for different learning methods (1 – undergraduate studies; 2 – graduate studies; 3 – learning and training in companies; 4 – internet-based learning; 5 – books and journals-based learning). To obtain a measure of consistency, a statistical test was applied involving the calculation of a coefficient of concordance (W) for the utility factor provided by experts (Siegel and Castellan 1988) using the SPSS computer package. Utility factors of competencies are sufficiently consistent at 0.05 level of significance ($\alpha < 0.05$) or smaller for all suggested competencies. For the round 4 survey, the experts were asked to reassess their score in the light of the average values scored by the panel.

Table 1: Results of round 2 – relative importance of competences

CME competencies as a learning outcomes of education processes	(%)
1. **Project management** (scheduling techniques, alternative procurement, WBS, CAP)	100
2. **Cost engineering** (techniques, modelling, planning, control, estimating and tendering)	100
3. **Construction law** (contract law, claims, forms, alternative dispute resolution, mediation)	100
4. **Production management** (concurrent eng., lean production, supply chain management)	100
5. **International construction** (market entry, growth, profitability and survival, local government and regulatory bodies, market trends)	100
6. **Risk and value management** (risk identification and quantitative approaches, integrated value and risk engineering and management)	100
7. **Development and investment** (valuation, NPV, rate of return, discounted cash flow)	100
8. **TQM** (TQM, sustainable construction, built environment, ISO 9000 and 14000)	88,88
9. **Accounting and financial analysis** (balance sheets, profit measurement, cash flow, profit and loss, financial ratios, budgeting)	88,88
10. **Business management** (organizational structures and culture, leadership, marketing, taxation, processes improvement, partnering)	77,77
11. **Human resources management** (organizational behaviour, innovation, market, recruiting, performances, learning)	55,55
12. **Strategic management** (planning, diversification, competitiveness, markets, portfolio)	55,55

The first seven competencies are project oriented, following industry project management orientation and tradition, and the last five are business and corporate oriented, with a broader educational perspective in the fields of business management, economics, finance and investment.

A set of utility factors from rounds 3 and 4 are shown at Table 2.

Table 2: Concordance coefficient of utility factors in rounds 3 and 4

Selection criteria	Kendall coefficient of concordance – W			Significance level – α	
	Round 3	Round 4		Round 3	Round 4
1.	0.551	0.639	16.0%	0.005	0.001
2.	0.513	0.507	—	0.009	0.009
3.	0.426	0.438	2.8%	0.030	0.025
4.	0.509	0.472	—	0.009	0.016
5.	0.904	0.929	2.8%	0.000	0.000
6.	0.638	0.739	15.8%	0.001	0.000
7.	0.741	0.802	8.2%	0.000	0.000
8.	0.735	0.755	2.8%	0.000	0.000
9.	0.690	0.899	30.3%	0.001	0.000
10.	0.387	0.475	22.7%	0.050	0.015
11.	0.545	0.540	—	0.005	0.006
12.	0.663	0.696	5.0%	0.001	0.001

Industry needs for project management competencies are in accordance with project management-oriented educational programmes (analysed by Oglesby (1990) and Betts and Wood-Harper (1994)) and educational research studies (Long 1997; Singh 1992; Lowe 1991; Wadlim 1985; Hancher 1985; Grinter 1955) which have shown strong industry and educational institutions belief that project management knowledge and skills and successful project execution are the fundamental key to corporate success.

Industry requirements for specific business management and economics competencies beyond a project management level is in accordance with many educational research studies (Chinowsky and Paul 1997; National Academy of Sciences 1995; National Science Foundation 1996), which have considered management knowledge and skills as a critical issue for long-term corporate and sustainable industry success.

CONCLUSIONS

Educational research in the field of programme quality enhancement strategies, IT support for programme development and monitoring, and adaptation of educational programmes to the construction industry needs, are important activities for programmes developers and educational researchers.

Research results have shown industry requirements for broader construction management and economics competencies. In order to successfully respond to industry requirements management and economics educational programmes have to become a mirror image of construction industry needs.

Considering the latest dynamic changes in contemporary business methods, and bearing in mind that lifelong learning is at the heart of the contemporary educational process, educating engineers to successfully manage their projects and companies could foster integrated innovation processes, organizational improvement and sustainable industry development.

REFERENCES

Betts, M and Wood-Harper, T (1994) Reengineering construction: a new management research agenda. *Construction Management and Economics*, **12**, 551–6.

Cayes, K (1998) Need to learn and why engineers may be poor students. *Management in Engineering*, **14**(2), 31–3.

Chan, A, Yung, E, Lam, P, Tam, C and Cheung, S (2001) Application of Delphi method in selection of procurement systems for construction projects. *Construction Management and Economics*, **19**(7), 699–718.

Chinowski, P (2000) *Strategic corporate management for engineering*. New York: Oxford University Press.

Chinowsky, P and Guensler, R (1998) Multidisciplinary civil engineering education through environmental impact analysis. *In*: J P Mohsen (Ed.) *1998 ASEE South-eastern Section Conference*, ASEE, 79–84.

Chinowsky, P and Paul, S (1997) Introducing multimedia cases into construction education. *In*: T Adams (Ed.) *4th Congress on Computing in Civil Engineering*, 122–8.

Corotis, R, Fox, R and Harris, J (1981) Delphi methods: theory and design load applications. *ASCE Journal of Structural Division*, **107**(6), 1095–1105.

DGEC (Directorate General for Education and Culture) (2005) *ECTS user guide*. Brussels.

Drucker, P F (1993) *Post-capitalist society*. New York: Harper Collins Publishers.

Dutton, D M, Amor, R W and Bloomfield, D P (1996) Knowledge-based systems and the internet: a future perspective. Paper presented at the W78 International Conference ‘Construction on the Information Highway’, Bled, Slovenia.

Edmunds, H (1999) *The Focus Group research handbook*. NTC Business Books.

Grant, R M (1996) Toward a knowledge-based theory of competitive advantage. *California Management Review*, **33**(3), 114–31.

Grinter (1955) *The Grinter Report*, ASEE Committee on Evaluation of Engineering Education. Washinghton, DC: ASEE.

Hancher, D E (1985) Construction education in civil engineering. *In*: G K Wadlin (Ed.) *ASCE Construction Education in Civil Engineering*, 232–40.

Long, R P (1997) Preparing engineers for management. *Management in Engineering*, **13**(6), 50–4.

Lowe, J G (1991) Interdisciplinary postgraduate education for construction managers. *Professional Issues in Engineering Education and Practice*, **117**(2), 168–75.

National Academy of Sciences (1995) *Reshaping the graduate education of scientists and engineers*. Washington, DC: National Academy Press.

National Science Foundation (1996) *Shaping the future: strategies for revitalizing undergraduate education.* Arlington, VA: National Science Foundation.

Oglesby, C H (1990) Dilemmas facing construction education and research in the 1990s. *Construction Engineering and Management*, **117**(2), 4–17.

Siegel, S and Castellan, N (1988) *Nonparametric statistics for the behavioural sciences*. New York: McGraw-Hill.

Singh, A (1992) Experienced-based issues in construction education. *Professional Issues in Engineering Education and Practice*, **118**(4), 388–402.

Stata, R (1989) Organizational learning – the key to management innovation. *Sloan Management Review*, **10**(3), 63–74.

Wadlim, G K (Ed.) (1985) *Challenges to civil engineering educators and practitioners: where should we be going?* New York: ASCE.

AN OVERVIEW OF CONSTRUCTION MANAGEMENT EDUCATION AND RESEARCH AT CENTRAL AND SOUTH-EASTERN EUROPEAN UNIVERSITIES

Anita Cerić[1] and Mladen Radujković

Faculty of Civil Engineering, University of Zagreb, Kaciceva 26, Zagreb, Croatia

The field of construction management has never had an adequate role in educational and research programmes at civil engineering faculties, especially in former socialist countries where all the attention was directed on the technical aspects of engineering. This paper will show how the restructuring of civil engineering curricula according to the Bologna Declaration affects the status of construction management education and research at the universities of central and south-eastern Europe. The research includes twelve universities from nine countries. The results show that there are significant differences within the region reflecting specific features of each country, and that the role of construction management has been increased.

Keywords: civil engineering, developing countries, education, learning, organization.

INTRODUCTION

The 25th anniversary of *Construction Management and Economics* is a good occasion to analyse the position of this field in some central and south-eastern European countries. Many of these former socialist countries have changed their political and economic systems and some of them became part of the European Union. As a part of the European community, they signed the "Bologna Declaration". Despite the fact that a few former and now lately independent Yugoslav countries have not yet joined the EU, they signed this Declaration on higher education as well.

The Bologna Declaration is an obligation undertaken by 29 countries to reform the structures of their higher education system in a convergent way. This commitment is freely taken by each country to reform its own education system. A set of specified objectives of the Declaration are: the adoption of the common framework of readable and comparable degrees; establishment of a system of credits (ECTS-European Credit Transfer System); students', teachers' and researchers' mobility; and quality assurance.

A few years have passed since signing the Bologna Declaration. At the South Eastern Network (SENET) conference held in Croatia earlier this year, the top experts from the fields of organization, management and technology in civil engineering came together to report on new educational programmes developed according to the research projects and the Bologna Process, and to comment on the implementation of the Bologna Declaration. Those reports were used to analyse the condition of construction management in this region.

[1] anita@grad.hr

METHODOLOGY

To get the insight into the status of construction management at the universities, the participants reported on their individual experiences. Representing their countries, the participants of the SENET symposium took part in the section "Education and Research in Construction". This paper reports on the experiences of twelve universities from nine countries. The reports analysed with regard to each individual country aimed to answer the following questions:

- Which institution organizes educational and research work for construction management?
- Which unit within the institution organizes educational and research work (an institute, department, chair)?
- Has the Bologna Process started and when?
- At what level is the construction management course being held within the undergraduate programme, i.e. is there any field connected with construction management or are there only construction management-related subjects?
- At what level is the construction management course being held within the graduate programme – i.e. is there any field connected with construction management or are there only construction management-related subjects?
- Has a postgraduate programme in the construction management field been organized?
- Do organization units conduct, prepare and take part in national and international research projects?

The answers served as a basis for the comparative analysis of construction management's position in the central and south-eastern European region.

ANALYSIS OF REPORTS WITH REGARD TO UNIVERSITIES

The reports covering twelve universities from nine countries were analysed. The participating countries were: Austria, Bosnia and Herzegovina, the Czech Republic, Croatia, Greece, Hungary, Kosovo (Serbia), Republic of Macedonia and Slovakia. Twelve universities were analysed in total (Table 1).

Table 1: Analysed universities

Country	City	University
Austria	Vienna	Vienna University of Technology
Bosnia and Herzegovina	Sarajevo	University of Sarajevo
Czech Republic	Brno	Brno University of Technology
Croatia	Rijeka	University of Rijeka
Croatia	Split	University of Split
Croatia	Zagreb	University of Zagreb
Greece	Athens	National Technical University of Athens
Hungary	Budapest	Budapest University of Technology and Economics
Kosovo (Serbia)	Pristina	University of Pristina
Republic of Macedonia	Skopje	Ss. Cyril and Methodius University, Skopje
Slovakia	Kosice	Technical University of Kosice
Slovakia	Bratislava	Slovak University of Technology, Bratislava

Table 2 shows which institution and unit organizes educational and research work for construction management and whether the Bologna Process has started and when.

Table 2: Institutions, units and starting time of Bologna Process

City	Institution	Unit	Bologna Process
Vienna	Faculty of Civil Engineering	Institute of Interdisciplinary Construction Process Management with three Departments: Department of Industrial Building and Interdisciplinary Planning, Department of Construction Management and Department of Construction Economy	2005/2006
Sarajevo	Faculty of Civil Engineering	Department of Technology and Organization	2006/2007
Brno	Faculty of Civil Engineering	Institute of Structural Economy and Management and the Institute of Technology, Mechanization and Construction Management	2004/2005
Rijeka	Faculty of Civil Engineering	Department of Construction Management, Technology and Architecture	2005/2006
Split	Faculty of Civil Engineering and Architecture	Department of Construction Management	2005/2006
Zagreb	Faculty of Civil Engineering	Department of Construction Management and Economics	2005/2006
Athens	Faculty of Civil Engineering	Department of Construction Engineering and Management	Not yet started
Budapest	Faculty of Architecture and Faculty of Civil Engineering	Department of Construction Technology and Management	2005/2006
Pristina	Faculty of Civil Engineering and Architecture	Chair for Organization and Road Construction	2001/2002
Skopje	Faculty of Civil Engineering	Department of Technology and Organization	2004/2005
Kosice	Faculty of Civil Engineering	Department of Building Technology and Building Materials	2005/2006
Bratislava	Faculty of Civil Engineering	Department of Building Technology and the Department of Economics and Building Industry Management	Report does not state clearly

Table 3 shows at what level the construction management course is being held within the undergraduate, graduate and postgraduate programmes, i.e. is there any field connected with construction management or are there only construction management-related subjects.

Table 4 shows teachers’ activities in conducting, preparing and participating in national and international research projects.

Table 3: Fields and subjects in undergraduate, graduate and postgraduate programmes

City	Undergraduate programme	Graduate programme	Postgraduate programme
Vienna	no field, six compulsory subjects	Field: construction management and geotechnics	Not yet established
Sarajevo	No field, four compulsory subjects	No field, one compulsory subject	Not yet established
Brno	Field: civil engineering management	Field: civil engineering management	Field: civil engineering management
Rijeka	No field, two compulsory and two optional subjects	No field, two optional subjects	Not yet established
Split	No field, two compulsory and one optional subject	No field, two compulsory and three optional subjects	Not yet established
Zagreb	No field, three compulsory and five optional subjects	Field: construction management	Field: project management in construction
Athens	No field, five compulsory subjects	No field, three compulsory subjects	Not established yet
Budapest	No field, five compulsory and two optional subjects	Field: construction management in the graduate programme of both faculties	Not established yet
Pristina	No field, one compulsory subject	No field	Not established yet
Skopje	No field in, one compulsory and one optional subject	No field, two optional subjects	Not established yet
Kosice	Field: construction management	Field: building technology and realization	Field: building technology
Bratislava	Field: building technology and management	Two fields: building technology and economics and building industry management	Field: building technology

Table 4: Teachers activities in national and international research projects

City	National research project	International research projects
Vienna	Conduct, prepare and take part	Conduct, prepare and take part
Sarajevo	-	-
Brno	Conduct, prepare and take part	Prepare
Rijeka	-	-
Split	Conduct, prepare and take part	-
Zagreb	Conduct, prepare and take part	Conduct, prepare and take part
Athens	Conduct, prepare and take part	Conduct, prepare and take part
Budapest	Conduct, prepare and take part	Prepare
Pristina	Conduct, prepare and take part	-
Skopje	Conduct, prepare and take part	-
Kosice	Conduct, prepare and take part	Prepare
Bratislava	Conduct, prepare and take part	Conduct, prepare and take part

COMPARATIVE REPORTS ANALYSIS

Research and educational activities in the field of construction management are being organized at all universities by the faculties of civil engineering except for the faculties at Priština and Split where civil engineering and architecture are taught at the Faculty of Civil Engineering and Architecture.

The faculties organizational structures is quite different. The Brno faculty has two institutes specializing in construction management. The Vienna Institute comprises three departments specializing in construction management. There are two departments specializing in construction management in Bratislava. Athens, Budapest, Sarajevo, Skopje, Split and Zagreb all have a construction management department. There are no independent departments specializing in construction management in Kosice, Pristina and Rijeka.

The implementation of the Bologna Process in undergraduate study began with many difficulties at all analysed universities, except for the one in Athens. It started earliest in Pristina in 2001, whereas it began at other faculties between 2004 and 2006, which means that there are no finished undergraduate students yet enrolled on the graduate study.

The most complete undergraduate programme in the field of construction management is to be found at the universities of Bratislava, Brno and Kosice. Their students can enrol on programmes that are entirely focused on construction management. Students at other faculties can enrol within the existing undergraduate programme on 1–6 compulsory and 1–5 elective subjects. The acceptable level of undergraduate education in construction management can be obtained at the faculties in Athens, Budapest, Vienna, Sarajevo and Zagreb, while the undergraduate level education should be necessarily raised at the faculties of Pristina, Rijeka, Skopje and Split.

The most comprehensive graduate programme in the construction management field is to be found at the Bratislava faculty where students can enrol in two exclusively construction management programmes. At the faculties of Brno, Budapest, Košice and Zagreb, there are graduate programmes specializing exclusively in construction management. The Vienna faculty has a graduate programme in construction management combined with geotechnics. Students at other faculties can enrol in 1–3 compulsory and 1–3 elective subjects within the existing graduate programmes. The education level should be raised here.

Postgraduate PhD programmes in the field of construction management are to be found at the faculties of Bratislava, Brno, Košice and Zagreb. The other faculties have no PhD programme, so should be planned for in the future.

The faculties at Athens, Bratislava, Vienna and Zagreb conduct, prepare and participate in national and international research projects in the field of construction management. The faculties at Brno, Budapest and Kosice conduct, prepare and take part in national research projects while preparing international ones. The faculties at Split, Pristina and Skopje conduct, prepare and participate in national research projects, but do not take part in international research projects, their preparation or implementation. The faculties at Sarajevo and Rijeka do not carry out, prepare and participate in national and international research projects. Except for the latter two faculties, this situation is satisfactory with a continually increasing number of research projects and inter-faculty collaborations on new projects.

CONCLUDING REMARKS

The Bologna Process started in central and south-eastern European Countries. It is too early to draw conclusions on the implementation results, as there are no finished undergraduate students to date. Nevertheless, there are already some inadequacies that should be overcome in future. Construction management education is fundamentally different between the faculties within the region, which essentially makes one of the basic fundamentals – allowing student mobility while ensuring corresponding quality – of the Bologna Process difficult.

The pioneering of new curricula according to the Bologna Declaration led to the significantly more vital construction management role at most faculties. The most complete construction management education at all levels within the region can be obtained at the faculties of Bratislava, Brno, Košice and Zagreb. A high construction management education level can be attained at the faculties of Athens, Budapest and Vienna. The construction management educational level should be raised at the faculties of Sarajevo, Split, Rijeka, Skopje and Pristina.

The researchers from the region are sufficiently and increasingly involved in national and international research projects. The teachers' and researchers' mobility as the prerequisite of the Bologna Process will inevitably lead to ever increasing collaboration and involvement in research projects including those faculties that currently fail to keep pace. Despite some vagueness and difficulties following the implementation of the Bologna Process, the teachers and researchers in the field of construction management at the faculties of civil engineering can be satisfied with the construction management's increasing role with regard to technical aspects of engineering.

REFERENCES

Car-Pusic, D (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Gyulay, J (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Ivanička, K (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Radujkovic, M et al. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia

Knezic, S (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Kovacic, I (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Kozlovska, M (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Mulavdic, E (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Pantouvakis, J.P. (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Rodiqi, I (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Ticha, A (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

Zileska-Pancovska, V. (2006) Education and research in organisation, technology and management. *In*: M Radujkovic *et al*. (Ed), *7thSENET Conference*, 20–2 September, Zadar, Croatia.

WORK–STUDY CONFLICT: MANAGING THE DEMANDS OF WORK AND STUDY IN BUILT ENVIRONMENT UNDERGRADUATE EDUCATION

Anthony Mills,[1] Helen Lingard and Ron Wakefield

School of Property Construction and Project Management RMIT University Melbourne Victoria 3000, Australia

Excessive work demands cause students to have less time available for study, which results in them missing lectures and tutorials. In addition, full-time students appear to be increasingly uninterested in connecting with the broader university experience, and are instead seeking to adopt a minimalist approach to education. This study seeks a more accurate understanding of why students undertake part-time work to the level that they do. This paper examines the extent of employment of undergraduate students enrolled in property and construction at RMIT University Australia. Students responded to a questionnaire on the duration and nature of their part-time work. The results indicate that students are working on average three days per week during semester time. Past research suggests that there is sufficient evidence that this will create work–study conflicts. However, the paper suggests that one of the major issues facing educators is that students themselves believe that part-time employment within their discipline benefits their long-term career. Hence they are reluctant to reduce their work commitment. The paper concludes by suggesting that some form of work-integrated learning process may benefit both the students' learning and their need to obtain work skills.

Keywords: learning, work–life balance, work study, workforce.

INTRODUCTION

In recent years, the cost of personally funding education has increased to such an extent that combining work and study is a necessity for many students (Curtis and Lucas 2001; Curtis and Williams 2002). In fact, Curtis and Williams (2002) write of the 'routinisation' of students combining study and part-time work, suggesting that this is now the norm.

Students seem to accept a view that education is subordinate to employment, and that a university exists to prepare individuals for the world of work. This statement is based on a study of over 500 students who were enrolled in construction-based undergraduate courses in five universities across Australia conducted by the authors a few years earlier (Lingard *et al.* 2003; Mills and Ashford 2004).

Graduates of construction courses enter an industry which is under-supplied with tertiary trained people and salary prospects are very good. This research asked students about their long-term motivations for work and contrasted this with their short-term financial imperatives. In addition, this research considers whether

[1] anthony.mills@rmit.edu.au

universities have a responsibility to their students to assist them in obtaining the best educational outcomes and not just provide them with pathways to a job.

The changing attitudes of students towards their own education are having an impact on the ability of universities to offer broad educational experiences. Past research by the authors (Mills and Ashford 2004; Lingard *et al*. 2003) has shown that students now adopt a minimalist attitude to tertiary education because they have become aware that a degree alone will not guarantee entry to a profession. The value of an undergraduate education is less than it once was. In addition, students are spending larger amounts of time undertaking part-time work. The paper suggests that professional work experience should be included in undergraduate courses in a more formalized manner.

Aims and objectives

This paper builds on previous work which measured the amount of paid work being undertaken by built environment students, comprising quantity surveying and construction and project management. The paper presents an exploratory analysis of the factors predicting construction undergraduates' work conflict with university study. The aims of this paper were to:

- explore the extent to which students work and study; and
- develop a model of the work–study interface, describing the conflict between paid work and study due to time commitments.

The conflict between one's work role and other life roles is an important aspect of the relationship between work and non-work life. Much research and theory building has focused on the conflict between work and family. For example, Greenhaus and Beutell (1985: 77) defined work–family conflict as 'a form of inter-role conflict in which the role pressures from the work and family domains are mutually incompatible in some respect'. In adult life work and family are primary life domains and researchers have developed and tested various models of the antecedents (e.g. work hours, number of children, etc.) and consequences (e.g. absenteeism, low job satisfaction) of work–family conflict. Very little theory development has related to the forms of inter-role conflict affecting adolescents or young adults in full-time education. However, the work–family literature provides a useful basis for this development.

Markel and Frone (1998) suggest that that, in adolescent life, work and education are likely to be primary life domains. Empirical evidence indicates that the number of hours spent in paid employment each week is positively associated with a sense of conflict between work and education among adolescents and young adults (Markel and Frone 1998).

Student attitudes to education

McInnis (2003) stated that the results of various studies over a number of years showed that undergraduate students are unclear about their obligations to the university, and tend to spend less time on tasks that improve their learning experience. Instead, students are more pragmatic about their study and view learning as a vehicle to obtain work. The emphasis is now focusing on the universities who are beginning to detect that modern students have lower expectations of higher education and consequently there is a lower demand for full educational experiences. This according to McInnis (2003) has reduced the student incentives to be engaged in the education process.

Other studies (e.g. Curtis 2000) have found that many students do not consider university to be a full-time occupation and that when not in class they are available to work. This attitude can have a detrimental effect on the cohesion of group work performed outside class and can consume the time available for extra reading around subjects (Watts 2002). This can lead to a climate of individuals straddling their academic work and the labour market while not being fully committed to the cultures of either (Hodgson and Spours 2000).

A model of the work and university interface

For the purposes of this study a model of the work–university interface was developed based upon a model of the work–family interface, proposed and tested by (Frone *et al.* 1997). This model uses work–study conflict as a key mediating variable in the relationship between the time demands of both work and university, students' satisfaction with work and university life and burnout. Thus it is suggested that time demands impact upon students' work–study conflict.

Work–university conflict represents the extent to which involvement in one role (e.g. work) interferes with students' ability to participate in the other role (e.g. university). However, consistent with the research on the work–family interface, work–university conflict is conceptualized as a bi-directional phenomenon. Therefore, a distinction is made between the extent to which participation in paid work interferes with students' ability to meet university responsibilities (work–university conflict) and the extent to which participation in university life interferes with students' ability to fulfil the requirements of their paid work (university–work conflict).

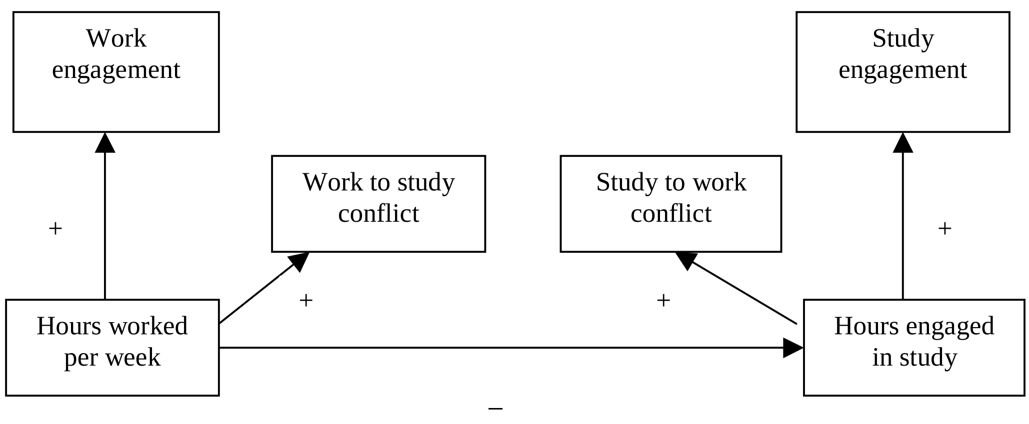


Figure 1: Hypothesized model of work–study interface

In the model (Figure 1), role-related time commitments are regarded as predictors of work–university conflict. Time is a limited resource and university students' time commitments to paid work reduce the time available to fulfil duties required of another role. It may therefore be expected that excessive time involvement in paid work would make the fulfilment of university requirements more difficult for students, giving rise to a sense of work–university conflict. Conversely, the time requirements of university might negatively interfere with students' work responsibilities, for example when a lecture clashes with a scheduled project meeting. Thus it was expected that there would be a positive relationship between the number of hours spent at university and university–work conflict.

This research focused on the motivations of students to seek work during semester time. The hypothesized model in Figure 1 has been used to validate work–study conflicts of construction students. The next section of this paper outlines the research instrument used to collect the data on student attitudes to work.

METHOD

The research was based on a paper-based questionnaire, which was adapted from similar studies of work–family conflict. Three academic members of staff from RMIT University were contacted; each was asked if they would assist by offering a questionnaire to their students enrolled in the RMIT University, property construction and project management courses. Students were asked to respond to questions on a number of issues including: the reasons for seeking work, the type of work undertaken, and the amount of time spent in paid employment and the amount of time spent studying during semester.

The survey forms were given to each course coordinator for distribution to students in class. The completed survey forms were returned anonymously into a closed box. The data were entered into an Excel spreadsheet, which was later converted in to SPSS for analysis. In addition, each course coordinator was asked to specify the total number of students enrolled in their courses. The overall response rate was 23% (104/450) indicating that the survey represents a sufficiently large sample of the courses (Table 2).

One of the principal aims of the research was to explore more deeply the impact of paid work on the undergraduate student study experience. Past research by the authors (Mills and Ashford 2004; Lingard *et al*. 2003) indicated that students were working sufficiently long hours to experience conflicts with university study. Work to study conflict was measured using a modified version of the bi-directional work–family conflict scale developed by Netemeyer *et al.* (1996). Items were reworded to replace aspects of family life with study or university life. For example, 'the demands of my work interfere with my home and family life' was changed to 'the demands of my work interfere with my study'. Items were rated on a seven-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

The next section presents the results of the questionnaire, including the amount of time students spend on work and study. In addition, the respondents were quizzed about their perceptions of their work–study conflicts, these data were then analysed to produce a model of the work–university interface.

RESULTS

The number of hours students work during semester time was relatively high. Table 1 indicates that students spend on average 24 hours per week engaged in part-time work during semester. This is slightly higher than the amount of time spent by students in a prior study of built environment courses around Australia. The results of previous research conducted by the authors (Mills and Ashford 2004; Lingard *et al*. 2003) showed that other university students averaged 18 hours of paid industry work per week during semester time.

Table 1: Average number of hours worked per week (Semester 2) by type and year

	Casual work	Industry-based work	Average
Year 1	19.0	5.3	17.1
Year 2	17.5	23.3	20.2
Year 3	19.8	17.1	17.7
Year 4*	26.2	41.1	38.1
Total	19.7	27.1	24.0

Note: * 4th year students are only enrolled in research projects that require only limited class attendance.

Table 1 shows the average number of hours worked each week by type of employment. Industry-based work comprised employment in junior positions in quantity surveying, construction and project management. Casual jobs were those that were not related to the construction industry, and did not have a career dimension that was relevant to the student's course of study.

Casual work (i.e. non-industry work) consumes the fewest hours each week (19.7 hours), while working in industry-related jobs consumes more time (27.1 hours). An independent sample t-test was conducted to assess whether there were significant statistical differences between the work types. Students working in industry-based occupations do work significantly more hours per week than those in casual employment at the 5% level ($t = –0.2.882$, $p = 0.005$).

As expected, the results of Table 2 shows that most students tend to work in industry-based jobs in the latter stages of their course. The results show that only 14% of Year 1 students work in industry; this rises to 80% by Year 4. This shift begins to occur from about the third year when students reduce their preference for casual-based work. This indicates that students perceive there is more benefit in pursuing industry-based work compared to casual work when it becomes available.

Table 2: Number of students undertaking work by type and year (Q6)

	Casual work	Industry-based work	Total
Year 1	19 (86%)	3 (14%)	22 (100%)
Year 2	12 (52%)	11 (48%)	23 (100%)
Year 3	6 (21%)	23 (79%)	29 (100%)
Year 4	6 (20%)	24 (80%)	30 (100%)
Total	43 (41%)	61 (59%)	104 (100%)

Motivations for seeking work

The survey asked respondents about their reasons for seeking work; the questions were based on a similar study by Lucas (1997). The students were offered a limited list of seven reasons for work. The results of the study (Table 3) indicate that financial gain was not the most important reason why students work. Instead, students believed that work was mostly undertaken because it benefited their long-term career, as well as their undergraduate studies.

The results of present research support the work of Lucas; students work for a variety of reasons but financial imperatives are not the main motivation. This result indicates that students perceive industry-based work is of greater educational/career development value than its ability to provide financial reward. This also supports the work of Micklewright *et al.* (1994) who suggested that the unknown future state of the industry encourages students to seek work as soon as possible.

Although the students stated that the most important reason they seek industry work is because it benefits their long-term career, it may be reasonable to suggest that the benefits may be due to maintaining industry contacts and developing a stronger resumé for future job applications. This may be occurring in spite of the negative impact on their educational experience at university.

Table 3: Indicate the extent to which the following statements relate to your reasons for work (disagree 1 to agree 5) (Q17)

Reason for work	Mean score	Rank
It benefits my long-term career	2.3	1
Because it is beneficial to my studies	2.7	2
To pay for my essential living expenses	2.7	2
To provide income for my social activities	2.7	2
To save money for special purposes	3.0	5
I feel it necessary to have a job in industry	3.1	6
The rates are better than for casual employment	3.8	7

An independent sample t-test was conducted to assess whether there were significant statistical differences between the reasons for work (Q17) between various groups within the survey. The results of Q17 were analysed by university, gender and course, and no statistical difference was evident at the 5% level. This indicates that student motivations for work are essentially the same across all major subgroups within the sample.

The overall results indicate that students engaged in a significant amount of paid work while enrolled as full-time students. There appears to be sufficient evidence that students may experience work–university conflicts. The next section of the paper examines students' perception of that conflict and whether it can be predicted by the time spent at work or engaged in university learning.

Factor analysis of work and study

Past literature on work–family conflict suggested that there were a number of issues that resulted from the amount of time students spent working and studying. A set of questions were devised to examine the effects of:

- work to study conflict;
- study to work conflict;
- work engagement;
- study engagement.

The questions in Table 4 show factor loadings that applied to the above aspects of work–study interfaces. A principal components factor analysis with varimax rotation confirmed the discriminant validity of the four dimensions. The results of this analysis are presented in Table 4. Items loaded clearly on the four factors which explained 76% of the variance.

The factor loadings were saved and correlated with the time spent in work and time spent engaged in study. The next section of the paper examines the correlations of each of the components and offers some possible explanations of the results.

Table 4: Factor analysis of work–study conflict

Survey question	Component			
	1	2	3	4
I am enthusiastic about my paid work	0.066	–0.072	0.812	0.136
My job really inspires me	–0.026	0.065	0.930	0.040
I find my job full of meaning and purpose	0.032	0.118	0.881	0.091
I am enthusiastic about my university study	–0.014	–0.012	0.187	0.861
My study really inspires me	–0.115	0.053	–0.052	0.936
I find my university study full of meaning and purpose	0.018	–0.183	0.153	0.868
The demands of my work interfere with my study	0.875	0.126	0.053	0.043
Because of my job I can't involve myself as much as I would like in my study	0.913	0.094	0.063	0.017
The things that I want to do at university do not get done because of the demands my job puts on me	0.864	0.213	–0.018	–0.140
There is conflict between my job and the commitments I have as a university student	0.831	0.319	–0.039	–0.076
The demands of my study interferes with work-related activities	0.463	0.618	0.122	–0.017
I sometimes have to miss work so that study responsibilities are met	0.422	0.691	0.182	0.046
Things I want to do at work do not get done because of the demands my university study puts on me	0.307	0.827	0.077	–0.064
My study interferes with my responsibilities at work, such as getting to work on time, accomplishing daily tasks and working overtime	0.251	0.833	0.058	0.026
My employers and/or co-workers dislike how often I am preoccupied with university life	–0.162	0.623	–0.186	–0.145

Notes: Extraction method: principal component analysis. Rotation method: varimax with Kaiser normalization. A rotation converged in 5 iterations.

Correlations

Bivariate Pearson correlations between the variables measured in the research are presented in Table 5. Inter-correlations between the factors and the work and study hours showed that little conflict seems to exist. Surprisingly only work to study conflict was significant. Contrary to expectations, neither the number of hours students spent in paid work nor the number of hours per week engaged in learning were significantly correlated with the study to work conflict dimension.

The results (Table 5) indicated that work to study conflict was also positively correlated with hours engaged in learning ($r = 0.264$, $p = 0.010$). Hours worked per week was negatively correlated with work to study conflict ($r = –0.371$, $p = 0.000$). And also hours work per week was also negatively correlated with hours engaged in learning ($r = –0.434$, $p = 0.000$).

Table 5: Bivariate correlations between the variables

	Factor	1	2	3	4	5	6
1.	Work to study conflict	1					
2.	Study to work conflict	0.000	1				
3.	Work engagement	0.000	0.000	1			
4.	Study engagement	0.000	0.000	0.000	1		
5.	Hours worked per week	–0.371**	–0.075	–0.016	0.170	1	
6.	Hours engaged in learning per week	0.264**	–0.063	0.152	–0.071	–0.434**	1

Note: ** Correlation is significant at the 0.01 level (2-tailed).

The results of the survey have shown that students seemingly work long hours in industry-based jobs while also engaged in full-time study. Past research indicated that this mix was a recipe for conflicts. The incidence of high levels of work does translate into work to study conflicts, but surprisingly not into study to work conflicts. This suggests that students are concerned more about meeting work obligations, and less worried about missing learning opportunities and study. The next section of the paper discusses the above findings and draws some conclusions.

DISCUSSION

Past research has shown that work in excess of the 10–15 hours per week is believed *not* to be beneficial to student learning (Curtis and Lucas 2001). The results of this research showed that students appear to be working longer than what may be considered useful to gain work skills. Instead, students appear to be increasingly uninterested in connecting with the broader university experience, and instead seek to adopt a minimalist approach to learning.

The results of the RMIT study validate the previous studies of other built environment courses across Australia. Students in built environment courses tend to work longer than average for all students in Australia which is 14.7 hours per week (Mcinnis 2003).

This seems to be supported by the results of Table 3 which shows that highest ranked reason for work was that it benefited their long-term career. The results show that students change their preference from casual work in the early part of their course to industry-based jobs in the later years. It seems that over time the benefits of casual jobs become more limiting because it is not possible to obtain career experience while undertaking non-industry work. The undergraduates in the study seek property- and construction-related positions as soon as they can in order to begin their careers.

The study confirmed that many students were working and studying for long hours during a typical semester week. This suggested that there is some evidence to suggest that work–study conflict exists, although the conflict seems to be asymmetrical and does not seem to affect students' ability to meet the demands of study. The next section explores some aspects of the conflicts as perceived by the student respondents.

Work to study conflict

Past research based on work–family conflicts suggested that impacts were expected to be bi-directional in nature. In other words, there should be both study to work conflict, and work to study conflict. The results of this research were somewhat surprising.

Students' experiences at the work–university interface are presently asymmetrical with students indicating a greater tolerance for the time demands of paid work than those of university study. Overall these findings suggest that the students in the present sample resent the time commitments required by university.

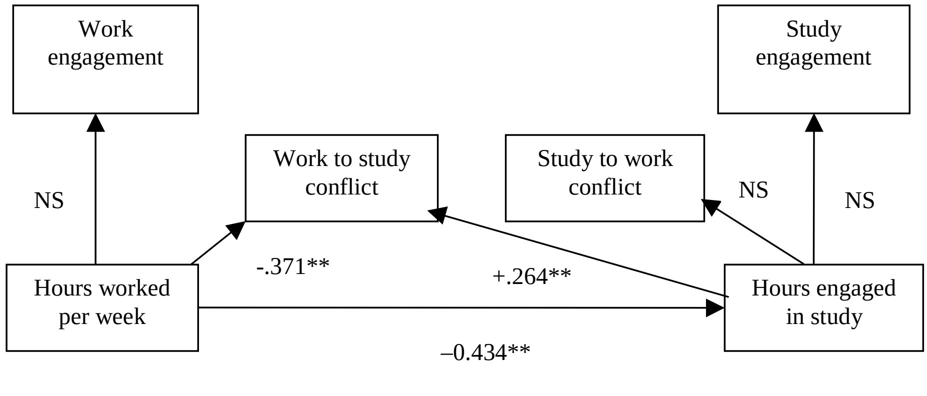


Figure 2: Correlation coefficients for work–university interface

Notes:** Correlation is significant at 0.01 level (2-tailed). NS Correlation is not significant.

Students who spend more time at work seem to spend less time at university engaged in study. The results of correlation analysis in Table 5 have been used to form the model in Figure 2. The model indicates that when students worked longer hours it reduced the time available for university but that contributed to less work to study conflict. In addition, there were no significant correlations with the study to work conflict.

The non-significant relationship between time involvement and students' perceptions of work–university conflict was unexpected. This finding indicates that work–university conflict does not mediate the relationship between time demands of work or university and the outcome variables measured in the study. This is in contrast to the role played by work–family conflict, which mediates the relationship between time demands of work and burnout in employed adults. This result also suggests that, among the students in our study, the amount of time spent in paid work may be a less significant source of work–university conflict than other variables. This finding is similar to a report by Ackerman and Gross (2003) that marketing students in an American university were less affected by a perceived scarcity of free time than by an individual's emotional reaction to work and university commitments.

Future research should examine the extent to which variables other than time involvement predict students' work–university conflict. Other variables of interest may include subjective perceptions of the qualitative and quantitative workload, available resources and support and the amount of control that the students are able to exercise over their work and university arrangements. Students' commitment to their work and/or their university education was not measured in this study but it is possible that these findings reflect that the role of employee is more salient to property and construction students than the role of university student.

CONCLUSIONS

In higher education research there is a growing interest in the importance of work-based learning, which is defined as linking learning to the work role. The significance of this research was that it demonstrated that when students worked longer hours it reduced the time available for university, but that it also contributed to less work to study conflict. In addition, there were no significant correlations with the study to work conflict suggesting that students placed greater value on work experience than on study, particularly in the final years of their course. If this is the case universities should consider whether the length and type of education on offer is still appropriate to students intending to enter the construction industry.

Garavan and Murphy (2001) suggested that work-based learning requires consensus and agreement from key players in the learning process, namely: the individual student, the employer and the higher education institution. Work-based learning helps to bridge the gap between theory and practice by permitting reflection on actions and the testing out and reapplying of theories when faced with dilemmas and when confronting new situations in the workplace. The results of this research suggest that some form of work-based learning may provide the necessary link between the students' need for work and the necessity for deeper educational experiences as a student.

Past research (Garavan and Murphy 2001) identified a number of different models of work-integrated learning, none of which has been examined in this research. For example, one model explores how each course could develop an alternative model of assessment so that students can choose to do either the standard piece or an equivalent work-based one, which draws on and uses their paid work experiences/activities. In other words, students could either do the assignments as set by their lecturer, or alternatively negotiate with the lecturer to undertake work-based tasks that can be used for academic assessment. This requires great care to ensure that lecturers can assess the work-based experiences against rigorous academic standards rather than just industry custom and practice, i.e. the alternative assessment must capture students' independent reflection and learning. This is also likely to require some cooperation and commitment from the students' employers.

Another model identified a set of capabilities in the programme which could give credit for a portfolio of evidence that documents the development of these capabilities from work-based activities. Multiple assessment options could be developed and spread across the programme or be clustered around discipline-specific capabilities. In this way recognition of concurrent relevant industry-based learning will be acknowledged and formalized. In other words, academic credit may be given to the acquisition of broad professional competences gained in the workplace. The research by Sher *et al.* (2004) matched work-based learning experiences with the development of professional competence of the Australian Institute of Building.

However, is unclear whether universities should require industry experience as a formalized component of the course. University policies generally do not allow students to be remunerated while undertaking practical work experience that is assessed as part of an undergraduate degree. While industry would readily accept free student practical experience labour, this may be an unreasonable expectation on the student as well as a financial burden. In addition, university monitoring of student experiences would then be necessary as part of the package for quality assurance purposes which leads to higher educational costs to the university.

Although there is substantial past research that shows that work can provide very positive benefits for obtaining employability skills, this study suggests that there are three major challenges. First, to identify the employability skills and attributes that students need to obtain. Secondly to identify the model for learning that best integrates their work and study experiences. Thirdly, to develop tools that allow students access to the learning experiences.

The development of a partnership between the university and the industry in providing work experience that complements the programme of study would be helpful. Without this partnership, students may not get the range of experience they need and may struggle to find the linkages between theory and practice. More research is needed to determine the form and structure of the work-integrated learning programme. Nevertheless the results of this research show that such a programme is likely to be very well received by students. Universities have a responsibility to their students to assist them in obtaining the best educational outcomes from their degree courses. Given the reality of student employment, this must include being flexible and supportive of students in paid work.

REFERENCES

Ackerman, D S and Gross, B L (2003) Is time pressure all bad? Measuring the relationship between free time availability and student performance and perceptions. *Marketing Education Review*, **13**, 21–32.

Curtis, S and Lucas, R (2001) A coincidence of needs? Employers and full-time students. *Employee Relations*, **23**, 38–54.

Curtis, S and Williams, J (2002) The reluctant workforce: undergraduates part-time employment. *Education + Training*, **44**, 5–10.

Frone, M R, Yardley, J K and Markel, K S (1997) Developing and testing an integrative model of the work–family interface. *Journal of Vocational Behavior*, **50**, 145–67.

Garavan, T and Murphy, C (2001) The co-operative education process and organisational socialisation: a qualitative study of student perceptions of its effectiveness. *Education + Training*, **43**(6), 281–302.

Hodgson, A and Spours, K (2000) *Earning and learning: a local study of part-time paid work among 14–19 year olds*. London: Institution of Education, Lifelong Learning Group.

Lingard, H, Mills, A and Ashford, P (2003) Patterns of semester-time employment among undergraduate property and construction students: a preliminary study. *In:* C Langston (Ed.) *AUBEA 2003: Working together, proceedings of the 28th Annual Australasian University Building Educators Association*, 9–11 July 2003, Deakin University, Geelong, Victoria, 19–34.

Markel, K S and Frone, M R (1998) Job characteristics, work–school conflict and school outcomes among adolescents: testing a structural model. *Journal of Applied Psychology*, **83**, 277–87.

McInnis, C (2003) New realities of the student experience: how should universities respond? Paper presented at the 25th Annual Conference of the European Association for Institutional Research, Limerick, Ireland.

Micklewright, J, Rajah, N and Smith, S (1994) Labouring and learning: part-time work and full time education. *National Institute Economic Review*, May, 73–85.

Mills, A and Ashford, P (2004) Full time student and part-time worker: employment practices of undergraduate students in built environment courses in Australia. *In*: G Runeson (Ed.) *Australian University Building Educators Association (AUBEA)*, 7–9 July 2004, Centre for Infrastructure and Property, The University of Newcastle, 188–200.

Netemeyer, R G, Boles, J S and McMurrian, R (1996) Development and validation of work–family conflict and family–work conflict scales. *Journal of Applied Psychology*, **81**(4), 400–10.

Sher, W, Williams, A, Sharkey, R and MaccKee, J (2004) NURAPID: a student-centred development tool for Australian universities. *In:* G Runeson (Ed.) *Australian University Building Educators Association (AUBEA)*, 7–9 July 2004, Centre for Infrastructure and Property, The University of Newcastle, 69–81.

Watts, C (2002) The effects of term-time employment of academic performance. *Education + Training*, **44**(2), 67–75.

LEADERSHIP RESEARCH IN THE CONSTRUCTION INDUSTRY: A REVIEW OF EMPIRICAL WORK AND POSSIBLE FUTURE DIRECTIONS

Shamas-ur-Rehman Toor[1] and George Ofori

Dept of Building, School of Design and Environment, National University of Singapore, Singapore 117566

Researchers have traditionally focused on technical and managerial features of construction projects and have largely ignored the subject of leadership. However, recent interest in the subject has resulted in global research initiatives that aspire to understand leadership in a more holistic manner. To further the research on the subject, it is important to review the existing body of knowledge and draft a road map for the future. For this purpose, a review of empirical works on leadership in the construction industry is reported in this paper. Findings reveal that most empirical studies focus on behavioural dimensions of leadership while ignoring numerous important dimensions, particularly leadership development. For future research, leadership studies need to improve quality in terms of research design, level of analysis, developmental perspective of leadership and objective measurement of leadership outcomes. Along with past and ongoing research trends, a brief agenda is discussed for further research in the area of leadership in the construction industry.

Keywords: construction industry, future studies, leadership, project management.

INTRODUCTION

For several years, the mainstream paradigm of construction industry leaders has been technology and project oriented (Pries *et al*. 2004) and focused on management, to the exclusion of leadership (Skipper and Bell 2006a). This conventional orientation of construction firms and conservative culture of the industry is resulting in a shortage of skilful ‘project leaders’ although it has produced a large number of ‘project managers’ (Toor and Ofori 2006). Other studies have noted that construction managers are hardly perceived as leaders and are often considered as managers (Russell and Stouffer 2003). The prevailing situation is, therefore, regarded as ‘leadership crises’ by some scholars who believe that construction leaders should be capable of changing the conventional paradigm of management in the industry and setting exemplary standards for other businesses to follow (see Toor and Ofori 2006).

The lack of focus on leadership is not only the case in practice; academic research also seems to have done little in the area (Odusami *et al*. 2003; Chan and Chan 2005). Langford *et al*. (1995) opine that the low volume of leadership studies in construction is due to the lack of knowledge of the industry on the part of social scientists and a lack of understanding of social sciences by those in the industry. In the construction literature, studies on leadership mostly concentrate on investigating the motivational factors and the personal characteristics of project managers (Dulaimi and Langford

[1] shamas@nus.edu.sg

1999). However, in recent years, there has been an increase in the number of publications with an expanded range of topics related to leadership in the construction industry.

The latest initiatives of the International Council for Research and Innovation in Building and Construction (CIB) have also resulted in formation of a task group on leadership in construction (TG64), which has released its ambitious plans. The introductory statement of TG64 articulates that "the challenges of globalization, new markets, changing demographics and new technologies are transforming the focus of construction leaders and require the implementation of new competitive strategies, forging of international alliances and the adoption of new practices. The industry needs to develop, implement and support the leadership required to successfully lead construction projects and organizations in the new construction environment."

To carry out more work on leadership in the construction industry and achieve the objectives of TG64, it is important to review the work that has been done on different sub-topics of leadership and consider where the state-of-the art research stand today. In the light of past research and ongoing changes in the global construction environment, a broader road map for leadership research in the construction industry can be prepared to meet the current needs and the long-term development of construction industry leaders. To put forward a future research agenda for leadership research in the construction industry, this paper presents a review of empirical works that have been carried out in the past. The main objectives of this paper are: (i) to review the published empirical work on leadership in the construction industry research literature; (ii) to identify the past and current research trends on the subject; and (iii) to propose the future research developments.

METHOD

To review empirical studies on leadership in the construction literature, a search was carried out in various online databases. Combinations of several keywords were used to search publications on leadership in the construction industry, which resulted in a broad selection of a large number of works that included empirical, qualitative and descriptive articles, notes, features, book reviews and case studies. To separate the empirical studies from the larger pool, the following selection criteria were established: (a) the study principally focuses on the subject of leadership; (b) the study is empirical in nature; (c) the study is carried out in the domain of the construction industry; and (d) the study is peer-reviewed and published in an international journal.

In addition to searching databases, various internationals journals in the domain of construction, engineering and project management were also searched. Thus, it is pertinent to note that this review focuses only on empirical studies published in peer-reviewed journals, and does not include any conference papers, research reports, unpublished dissertations, feature articles, magazine articles, theoretical and conceptual papers, and any books or book reviews. Restriction of scope to empirical work is in order to avoid any possible confusion between theoretical and empirical work. This restriction is helpful to clearly define the scope of review, present explicable and objective findings, and make recommendations for future work. The review is also limited to studies in the English language. Considering the above criteria, studies were coded and further short listed resulting in a list of 39 articles. Reference lists in all the selected articles were again checked to circumvent the chance of missing any studies. Consequently, five more studies were included in the review list. In the second stage, these studies were further coded with respect to their research framework, study objectives, methodology, type of respondents, country of research, principal outcomes of study, future research directions, and so on. In the following sections, some findings from the review are presented.

Table 1: Summary of findings

Distribution of publications in JOURNALS		Distribution of Publications over YEARS		Distribution of studies over various FRAMEWORKS	
Journal Title	**N***	**Year**	**N**	**Framework**	**N**
International Journal of Project Management	12	Before 1990	2	Fiedler's Least Preferred Coworker (LPC) Scale	9
Construction Management and Economics	10	1990–1995	4	Blake and Mouton's Leadership Grid	4
ASCE *Journal of Management in Engineering*	8	1996–2000	15	Heresy and Blanchard 4 Factor Model	2
ASCE *Journal of Construction Engineering & Management*	3	2001–2005	17	Bass and Avolio Multifactor Leadership Questionnaire (MLQ)	2
Journal of Managerial Psychology	3	2006–2007	5	Behaviorally Anchored Rating Scale (BARS)	2
Project Management Journal	2			Weber's Taxonomy of Authority	1
Journal of Construction Innovation	2			David McCleland's Managerial Style Questionnaire (MSQ)	1
Journal of Construction Research	1			Dulewicz and Higgs Leadership Competencies	1
Building Research and Information	1			Pinto and Slevin Ideal Leadership Style	1
International Journal of Human Resource Management	1			Kouzes-Posner Leadership Practices Inventory (LPI)	1
Journal of Occupational Psychology	1				

* N denotes the number of studies

FINDINGS

Some general observations from the review are shown in Table 1. It indicates that most studies have been published in the *International Journal of Project Management* followed by *Construction Management and Economics* and ASCE *Journal of Management in Engineering*. It is also apparent from Table 1 that most studies have been carried out in the UK followed by USA, Hong Kong, Singapore and Thailand. Some studies are conducted in more than one country (e.g. Chan and Chan 2005; Powl and Skitmore 2005; Muller and Turner 2007). The distribution of the studies according to the time of publication reveals that very few studies are published before 1996. However, the last decade has witnessed a considerable increase in leadership studies in the construction industry.

A summary of the frameworks that researchers have employed in their investigations on leadership-related topics is summarized in Table 1. It can be seen that Fiedler's (1967) Least Preferred Coworker (LPC) scale has been used most frequently, followed by Blake and Mouton's (1978) nine-factor leadership grid. Despite its widespread use in the mainstream leadership studies, Bass and Avolio's (1990) transformational leadership (or MLQ) has been employed only in two of the studies considered. In most studies in this review, researchers have used their own questionnaires, interviews, or case studies to analyse and describe the leadership behaviour of their respective subjects. Table 1 also shows that studies included in the review target a wide range of construction professionals. Most studies have focused on project managers, site managers, project professionals, project engineers and building professionals. Few studies have been conducted on executive level managers and other professionals such as quality managers and quantity surveyors. In few studies, foremen have been either included as raters in a 360 degree loop (Ogunlana *et al*. 2002) or as principal subjects (Seymour and Elhaleem 1991).

RESEARCH TRENDS IN THE PAST

Dulaimi and Langford (1999) observe that most studies on leadership in the construction industry concentrate on investigating the motivational factors and the personal characteristics of project managers. This review also confirms that more than 30% of studies directly or indirectly address leadership dimensions such as behaviours, traits, characteristics and attributes (e.g. Seymour and Elhaleem 1991; Muir and Langford 1994; Dulaimi and Langford 1999; Fraser 2000; Cheung *et al*. 2001; Ogunlana *et al*. 2002; Carr *et al*. 2002; Odusami 2002; Dulaimi 2005; Butler and Chinowsky 2006; Skipper and Bell 2006).

However, recently some research works have been published on leadership development (Skipper and Bell 2006), emotional intelligence (Butler and Chinowsly 2006), superior-subordinate relationship (Lee *et al*. 2005), leadership in multi-cultural projects (Makilouko 2004), effectiveness of leadership and innovation (Bossink 2004; Nam and Tatum 1997), thinking style for managing change (Tuilett 1996) and emerging managerial competencies (Debrah and Ofori 2005). Research on factors that hinder the leadership performance of project managers also continues to attract researchers (see Mustapha and Naoum 1998; Zimmerer and Yasin 1998; Powl and Skitmore 2005; Low and Chuan 2006). Another research trend that continues to persist is power and authority of leadership in construction organizations (e.g. Feng and May 1997; Fellows *et al*. 2003; Anita and Fang 2006).

Some research endeavours have also been devoted to match project managers with projects based on various personality dimensions (Ogunlana *et al*. 2002; Muller and Turner 2007). The majority of the leadership studies selected in this review also focus on effectiveness, performance or simply the job-related outcomes of leadership (Chan and Chan 2005; Fraser 2000; Fraser 1999; Djebarni 1996; Mustapha and Naoum 1998; Seymour and Elhaleem 1991; Odusami *et al*. 2003; Carr *et al*. 2002; Bossink 2004; Powl and Skitmore 2005). Similar contemporary and nascent research trends on leadership in the construction industry have also been summarized by Goodman and Chinowsky (2000) and are shown in Table 2.

Table 2: Current and emerging focal areas in leadership research

Leadership	**Current Focal Area**	**Emerging Focal Area**
	Academic management curriculum	Decision making under uncertainty
	Developing leaders and managers	Negotiation
	Leadership skills and traits	Senior management teams
	Organization culture, structure and dynamics	Pricing
		World-place politics
		Working with investors
		Ethics
		Coaching
		Managing organizational change
Managing People	Benefits programmes	Career development
	Employee performance	Workplace diversity
		Manager performance
		Work-family conflict
		Women executives
		Recruiting and training
		Workplace regulations

Source: Goodman and Chinowsky (2000)

IMPORTANT ISSUES AND FUTURE DIRECTIONS

Leadership constructs

From the review presented earlier, it can be noticed that leadership research in the construction industry has predominantly used very few leadership constructs that include contingency theory, leadership grid and transformational leadership. For example, no empirical studies have been carried out on charismatic, servant, spiritual, shared and authentic leadership. This review will help to comprehend what leadership style is most suitable under different circumstances and stages of a construction project. It will help to explore which leadership approach is most suitable for attaining particular objectives, such as to enhance construction productivity or the quality of the project management. It will also help to develop a framework that is most suitable for leadership development in construction industry professionals.

Level of analysis

Most studies have focused on leadership of project managers, site managers and construction professionals. However, studies have shown that foremen and supervisors also have a vital role in getting the job done on the construction site. Therefore, it is important to analyse the leadership at all levels of construction organizations. Examinations at dyadic, group and organizational levels also have the potential to enhance the understanding of leadership in the construction industry. Analysis should also be extended to examine the leadership issues in the cross-cultural and cross-organizational teams that have become a common feature on construction projects, especially those undertaken by joint ventures and consortiums.

Design of studies

In this review, it is noticed that most studies utilize the traditional approach of survey questionnaires and interviews. There are few case studies of firms and individuals; however, the methodology adopted in these does not go beyond interviewing the subjects or analysing some official documentation to capture certain leadership behaviours. Further, it is also found that the majority of the studies in this review are cross-sectional in nature. Leadership, being temporal in nature (Goodman *et al*. 2001; Avolio and Gardner 2005), must be examined through longitudinal studies. Particularly, in construction projects, some researchers have argued that project managers tend to employ different leadership styles during different stages of the project. This conclusion needs further exploration through longitudinal studies. Such studies can also explore how project managers adapt themselves to new projects and what influences their leadership styles in a new environment.

Multidimensional studies can examine the leadership style of those project managers who lead a number of projects at the same time. It is likely that they employ different styles in different situations, team composition and project variables that require a different leadership approach. It is pertinent to explore how they manage to perform under various situations and environments, through longitudinal and multidimensional studies.

Researchers in mainstream leadership research have used several innovative ways to study leadership. Particularly many have employed qualitative methods to analyse the leadership style and behaviour of their target subjects. Observational studies have also interested several scholars, especially in the case of transformational and charismatic leadership studies. Studying leadership through narratives, personal writing, stories or biographies has also been employed by many. Recently, psychometric neuro-scientific methods have also generated much interest in the study of leadership behaviour.

These studies can also focus on how the authenticity of leadership is perceived differently in different contexts such as: culture, religion, ethnicity and gender. Other dimensions on which project leadership research can focus are organizational culture (transactional, transformational etc.), type of organization (developers, contractors, architects, designers, quantity surveyors etc), size of organization (small, medium, large; local, multinational, etc.) and focus of organizational activity (building, roads, and so on). Such multi-level and multi-dimensional analyses can help to identify and explain specific leadership needs and demands of organizations in different contexts; and understand the tactics that leaders use to be more effective and successful in different contexts.

Leadership development

The review in this paper reveals that few leadership studies in the construction literature focus on leadership development and almost no works have considered designing effective interventions for leadership training and development of construction professionals. Industry has so far relied on professionals and managers educated on conventional academic curricula, and the organic growth of leaders through experience. However, in today’s competitive environment, there is a need to accelerate the leadership development process of capable individuals. Competitive advantage can be obtained by investing in leadership training and development of professionals at all levels of organizations. For this purpose, it is important to explore the antecedents that stimulate the leadership schema and result in leadership development. Research endeavours in this direction are likely to produce results that are useful for designing leadership development programmes for construction professionals. Future research can also focus on designing and testing interventions to develop special skills required to lead in the construction industry.

Leadership outcomes

The review in this paper shows that leadership studies mostly base their conclusions on perceptions of respondents without providing objective measurement of outcomes of leadership process. Hence, there is a need to evaluate leadership performance by objective measurements such as general effectiveness and performance, follower satisfaction, organizational and project performance, personal growth of leaders, influence on innovation, effectiveness in terms of cost, time and quality, management and satisfaction of stakeholders, decision making and dispute resolution capabilities, interface management, etc. Objective measurement of leadership outcomes will help to estimate return on the investment in leadership development programmes.

CONCLUSION

The principal purpose of this paper is to analyse key aspects of the published leadership research in the construction industry. The paper details various past trends, predicts several future trends and suggests certain areas in which future research on leadership in the construction industry could focus. The authors argue that leadership research and development should be undertaken at a macro-scale so as to transformation the industry's culture. It is also suggested that comprehensive analyses of descriptive studies, unexplored models and qualitative studies should also be performed to mark what has been done and what needs to be done on leadership in the future research.

The present authors hope that more studies on leadership in construction will be undertaken in the countries with mature construction industries such as Europe, the US and Japan, as well as those have, or are expected to have, large volumes of construction work such as Brazil, China, India, Russia, South Africa and the United Arab Emirates. Finally, it is hoped that CIB TG64 will provide the leadership in the work that is necessary in this important area.

REFERENCES

Note: References carrying '*' are the empirical studies selected for this review

*Anderson, S D (1992) Project quality and project managers. *International Journal of Project Management*, **10**(3), 139–44.

Avolio, B J, and Gardner, W L (2005) Authentic leadership development: Getting to the root of positive forms of leadership. *The Leadership Quarterly*, **16**(3), 315–38.

Blake, R R and Mouton, J. S. (1978) *The New Managerial Grid*. Houston TX: Gulf.

*Bossink, B A G (2004) Effectiveness of innovation leadership styles: a manager's influence on ecological innovation in construction projects. *Journal of Construction Information*, **4**, 211–28.

*Bresnen, M J (1986) The Leader Orientation of Construction Site Managers. *ASCE Construction Engineering and Management*, **112**(3), 370–86.

*Bryman, A, Bresnen, M, Ford, J, Beardsworth, A and Keil, T (1987) Leader orientation and organizational transience: An investigation using Fiedler's LPC Scale. *Journal of Occupational Psychology*, **60**, 13–19.

*Butler, C J, and Chinowsky, P S (2006) Emotional Intelligence and Leadership Behavior in Construction Executives. *Journal of Management in Engineering,* **22**(3), 119–25.

*Carr, P G, de la Garza, J M and Vorster, M C (2002) Relationship between Personality Traits and Performance for Engineering and Architectural Professionals Providing Design Services. *Journal of Management in Engineering*, **18**(4), 158–66.

*Chan, A T S and Chan, E H W (2005) Impact of Perceived Leadership Styles on Work Outcomes: Case of Building Professionals. *ASCE Construction Engineering and Management*, **131**(4), 413–22.

*Cheung, S O, Thomas Ng, S, Lam, K C and Yue, W M (2001) A satisfying leadership behavior model for consultants. *International Journal of Project Management*, **19**, 421–9.

*Dainty, A, Cheng, M and Moore, D (2005) A comparison of the behavioral competencies of client-focused and production-focused project managers in the construction sector. *Project Management Journal*, **36**(1), 39–48.

*Debrah, Y A and Ofori, G (2005) Emerging managerial competencies of professionals in the Tanzanian construction industry. *Human Resource Management*, **16**(8), 1399–414.

*Djebarni, R (1996) The impact of stress in site management effectiveness. *Construction Management and Economics*, **14**, 281–93.

*Dulaimi, M F (2005) The influence of academic education and formal training on the project manager's behaviour. *Journal of Construction Research*, **6**(1), 179–93.

*Dulaimi, M and Langford, DA (1999) Job Behavior of Construction Project Managers: Determinants and Assessment. *ASCE Journal of Construction Engineering and Management*, **125**(4), 256–64.

*Fellows, R, Liu, A and Fong, C M (2003) Leadership style and power relations in quantity surveying in Hong Kong. *Construction Management and Economics*, **21**, 809–18.

Fiedler, F E (1967) *A Theory of Leadership Effectiveness*. New York: McGraw-Hill.

*Fraser, C (1999) A non-results-based effectiveness index for construction site managers. *Construction Management and Economics,* **17**, 789–98.

*Fraser, C (2000) The influence of personal characteristics on effectiveness of construction site managers. *Construction Management and Economics*, **18**, 29–36.

*Giritli, H and Topcu-Oraz, G (2004) Leadership styles: some evidence from the Turkish construction industry. *Construction Management and Economics*, **22**, 253–62.

Goodman, P S, Ancona, D G, Lawrence, B A and Tushman, M L (Eds.) (2001) Special topic forum on time and organizational research. *Academy of Management Review*, **26**, 506–663.

Goodman, R E and Chinowsky, P S (2000) A Taxonomy of Knowledge Requirements for Construction Executives. *ASCE Journal of Management in Engineering*, 16(1), 80–9.

Langford, D A, Fellows, R, Hancock, M and Gale, A (1995) *Human Resource Management in Construction.* London: Longman.

*Lee, T S, Lee, D W, Lee, H and Park, H S (2005) Superior–Subordinate Relationships in Korean Civil Engineering Companies. *Journal of Management in Engineering*, **21**(4), 159–63.

*Liu, A M M and Fang, Z (2006) A power-based leadership approach to project management. *Construction Management and Economics*, **24**, 497–507.

*Low S P and Chuan, Q T (2006) Environmental factors and work performance of project managers. *International Journal of Project Management*, **21**(1), 24–37.

*Low, S P and Chuvessiriporn, C (1997) Ancient Thai battlefield strategic principles: lessons for leadership qualities in construction project management. *International Journal of Project Management*, **15**(3), 133–40.

*Low, S P and Lee, B S K (1997) East meets West: leadership development for construction project management. *Journal of Managerial Psychology*, **12**(6), 383–400.

*Low S P and Leong, C H Y (2001) Asian management style versus Western management theories A Singapore case study in construction project management. *Journal of Managerial Psychology*, **16**(2), 127–41.

*Low, S P and May, C F (1997) Quality management systems: a study of authority and empowerment. *Building Research and Information*, **25**(3), 158–69.

*Makilouko, M (2004) Coping with multicultural projects: the leadership styles of Finnish project managers. *International Journal of Project Management*, **22**, 387–96.

*McCabe, S, Rooke, J, Seymour, D and Brown, P (1998) Quality managers, authority and leadership. *Construction Management and Economics*, **16**, 447–57.

*Muir, I and Langford, D (1994) Managerial behavior in two small construction organizations. *International Journal of Project Management*, **12**(4) 244–53.

*Muller, R and Turner, J R (2007) Matching the project manager's leadership style to project type. *International Journal of Project Management*, **25**, 21–32.

*Mustapha, F H and Naoum, S (1998) Factors influencing the effectiveness of construction site managers. *International Journal of Project Management*, **16**(1), 1–8.

*Nam, C H and Tatum, C B (1997) Leaders and champions for construction innovation. *Construction Management and Economics*, **15**, 259–70.

*Noypayak, W and Speece, M (1998) Tactics to influence subordinates among Thai managers. *Journal of Managerial Psychology*, **13**(5/6), 343–58.

*Odusami, K T (2002) Perceptions of Construction Professionals Concerning Important Skills of Effective Project Leaders. *Journal of Management in Engineering*, **18**(2), 61–7.

*Odusami, K T, Iyagba, R R O and Omirin, M M (2003) The relationship between project leadership, team composition and construction project performance in Nigeria. *International Journal of Project Management*, **21**, 519–27.

*Ogunlana, S O, Niwawate, C, Quang, T and Thang, L C (2002) Effect of Humor Usage by Engineers at Construction Sites. *Journal of Management in Engineering*, **22**(2), 81–8.

*Ogunlana, S O, Siddiqui, Z, Yisa, S and Olomolaiye, P (2002) Factors and procedures used in matching project managers to construction projects in Bangkok. *International Journal of Project Management*, **20**, 385–400.

*Powl, A and Skitmore, M (2005) Factors hindering the performance of Construction Project Managers. *Journal of Construction Information*, **5**, 41–51.

*Rowlinson, S, Ho, K K T and Ph-Hung, Y (1993) Leadership style of construction managers in Hong Kong. *Construction Management and Economics*, **11**, 455–65.

Russell, J S and Stouffer, B (2003) Leadership: Is It Time for an Educational Change? Editor's Letter, *Leadership and Management in Engineering*, **3**(1), 2–3.

*Seymour, D and Elhaleem, T A (1991) 'Horses for courses' – effective leadership in construction. *International Journal of Project Management*, **9**(4), 228–32.

*Shoura, M M and Singh, A (1998) Motivation parameters for engineering managers using Maslow's Theory. *Journal of Management in Engineering*, **5**(5), 44–55.

*Skipper, C O and Bell, L C (2006a) Assessment with 360° Evaluations of Leadership Behavior in Construction Project Managers. *Journal of Management in Engineering*, **22**(2), 75–80.

*Skipper, C O and Bell, L C (2006b) Influences Impacting Leadership Development. *Journal of Management in Engineering*, **22**(2), 68–74.

Toor, S R and Ofori, G (2006) An Antecedental Model of Leadership Development. *In: Proceedings of Joint International Symposium of CIB Working Commissions W55/W65/W86,* October, Rome, Italy.

Toor, S R (2006) Leadership Flashback: An Antecedental Approach to Authentic Leadership Development. *In: Proceedings of the Second Biennial Gallup Leadership Institute Summit,* October, Washington DC, USA.

*Tuilett, A D (1996) The thinking style of the managers of multiple projects: implications for problem solving when managing change. *International Journal of Project Management*, **14**(5), 281–7.

*Walker, A and Newcombe, R (2000) The positive use of power on a major construction project. *Construction Management and Economics,* **18**, 37–44.

*Zimmerer, T W and Yasin, M M (1998) A leadership profile of American project managers. *Project Management Journal*, **29**(1), 31–8.

LIVE YOUR LEGACY, THAT IS WHAT YOU LEAVE: FUTURE ASPIRATIONS OF LEADERS OF SINGAPORE CONSTRUCTION INDUSTRY

Shamas-ur-Rehman Toor[1] and George Ofori

Department of Building, School of Design and Environment, 4 Architecture Drive, National University of Singapore, 117566

Leadership has been looked at through various lenses such as behaviours, styles and skills. Recent works have attempted to view leadership from the lens of the legacies that leaders want to leave behind. The legacies of the leaders do not only provide a perspective about the impact they want to have on the people and organizations but also portray the future they want to see. Interviews with leaders of professional organizations and AEC firms in Singapore show their desires for developing their followers as leaders and turning their firms into successful organizations. The interviews also reveal the anxiety of the leaders about issues in the industry such as lack of professionalism and adversarialism. Thinking about leadership purpose and leaving a legacy is not something the leaders should be doing in the last stages of the careers. Rather, the leaders should be clear about what they want to achieve from their leadership and what impact they want to have on their followers and organizations. This can help the leaders to understand and then live the legacies they want to leave behind.

Keywords: construction leaders, leadership, legacy, purpose, Singapore.

INTRODUCTION

Good leaders live the legacies they wish to leave behind. In their daily actions, decisions, interactions and communications, intentionally or otherwise, they demonstrate their inner values, beliefs and motivations. With every passing day, they leave an impression and make an impact on others; this may be positive or negative. Thus, Blanchard (in the foreword of Brooks *et al*. 2004) notes: ‘The legacy you live is the legacy you leave’. One common desire among good leaders is that they want to have a lasting impact on their followers and organizations. Some who are involved in social activities also wish to influence society in the long term. They want to be remembered in good lexis.

Galford and Maruca (2006) note that good leaders want to achieve success while looking into the future, whereas looking into the past, they would like to know that their efforts were appreciated and perceived positively by their followers and colleagues. They wish to think that they influenced people in a constructive manner and their efforts made a difference. They like to be remembered for the accomplishments they attained for their organizations and their people. Although ‘leadership legacy’ carries a positive connotation, it is important to acknowledge that a legacy does not have to be necessarily positive. However, good leaders want to leave good legacies.

[1] shamas@nus.edu.sg

This study seeks to discover the legacies which leaders in the construction industry of Singapore would like to leave behind. The articulation of such legacies would indicate: the future the construction leaders foresee; the changes they desire to occur in their own organizations and the construction industry; and what the leaders wish to leave behind in their organizations, their professions and the construction industry.

WHAT IS LEADERSHIP LEGACY?

Galford and Maruca (2006) consider a legacy as the enduring impact which a leader has on colleagues, followers, successors, organizations and external stakeholders. A legacy is the scale and scope of a leader's influence on others during the leader's period of time in a given position or in a given company, all these coloured by the judgment, or guiding principles, that the leader applies most consistently in his/her decisions (Galford and Maruca 2006). Brooks *et al*. (2004) consider leadership legacy as the 'sum of total difference' a leader makes in people's lives. This 'difference' can be direct or indirect, intentional or unintentional, short-term or long-term. Freeman (2004) maintains that the 'true legacy' a business leader leaves behind 'is what happens to the company' after the leader has completed the term of office, or departed. Nash and Stevenson (2004) note that legacy is a way to establish values or accomplishments so as to help others to find their own success in future, and is attained by investing in people, innovation, customer needs and systems. There are important questions to consider here: what kind of impact leaders want to have on others; who should receive more or less of the impact; and how long the impact should last.

Galford and Maruca (2006) argue that leadership legacy must not be equated with, or related to, vision, mission and strategy. They observe that vision, mission and strategy have their roots in the organization. On the other hand, legacy is grounded in the individual. It is not all about what people think about the leaders after they leave. It is rather the values and ideals they leave behind. It is important to note that leadership legacy seems to have a strong association with leadership purpose that has been considered to be fundamental to leadership development and effectiveness (George and Sims 2007; George 2003). If the leaders have a sense of purpose and they want to achieve a goal in their leadership, they find congruence between their purpose, motivations, needs of followers and expectations of their organizations (George 2004). The 'understanding of purpose' is analogous to 'leadership legacy', which implies that leaders with a sense of purpose want to create a difference in their organizations and in the lives of their followers by creating, living and leaving powerful and positive legacies.

LEGACY LEADERSHIP

While explaining the concept of legacy, Whittington *et al*. (2005) present the model of 'legacy leadership'. They suggest that 'the legacy of the leader's influence is perpetuated through the followers' incorporation of legacy principles into their lives as they become leaders' (Whittington *et al*. 2005: 749). Such leaders who are able to establish positive values and inculcate the 'legacy principles' into followers and organizations are called 'legacy leaders'. The theoretical model of 'legacy leadership' purports that the behaviour of such leaders is consistent with their internal motivation. As a part of their theory, they present three propositions:

> the motives of a legacy leader will influence the leader's choice of methods; the effects of a legacy leader's motives and methods on the followers' changed lives will be mediated by the followers' perceptions of those motives and methods; the impact of legacy leadership will be measured by changes in followers' lives that come to reflect the motives and methods of their leaders.

An example of the successful transmission of a leader's 'legacy principles' into the followers and the organization is the Nelson Mandela Foundation. The Foundation notes (www.nelsonmandela.org) that 'living the legacy of Nelson Mandela means incorporating his values into the work that we do. And that doesn't only refer to content; it refers to how we work. There has to be a high degree of professionalism, passion and commitment to push the boundaries of change. There has to be openness and transparency. And above all, there has to be the belief that no one person or organisation has all the answers.'

Mr Mandela left a strong impact on his followers, and the organization he established. He had qualities of 'legacy leadership' which Whittington *et al*. (2005) describe as: worthy of imitation, boldness amid opposition, pure motive, influence without asserting authority, affectionate and emotional, vulnerable and transparent, authentic and sincere, active, not passive, follower-centred and not self-centred.

METHODOLOGY

This paper reports on part of a study on leadership development in construction professionals in Singapore. It is based on interviews with 10 leaders in the Singapore construction industry. These leaders include past and present presidents of various professional organizations and trade associations, and chief executive officers (CEO) and directors of architectural, engineering and construction (AEC) firms in Singapore.

The questions asked during the interviews related to: (1) the interviewees' leadership philosophy; (2) the influence of significant individuals and events on the leadership development of the interviewees; (3) key turning points in their leadership development; (4) the personal and professional challenges they have faced; (5) what they want to achieve as leaders; and (6) the legacy the interviewees hope to leave behind as leaders. This paper reports on the findings from the last two questions covered in the interviews.

PURPOSE AND LEGACY: INTERVIEW RESPONSES

All the interviewees described their leadership purpose, what they wanted to achieve and the legacy they would like to leave behind. The discussion may be considered under the following themes:

- Developing the leader's followers and finding a successor
- Bringing about the positive changes the leaders desire to see in their organizations
- Bringing about the changes they would like to see in the construction industry in Singapore
- Leaving a legacy of the leader

DEVELOPING THE FOLLOWERS AND FINDING A SUCCESSOR

When the interviewees were asked what they wanted to achieve from the leadership roles they were playing, their responses related mostly to what they perceived as the purpose of their leadership roles. Most of the leaders wanted to develop their followers to be better professionals. For example, one of them, the managing director of a contracting firm, said:

> I want my staff to pick up knowledge of the field and to see the big picture. If they are able to see the big picture, it will be better for them as well as for the organization. I lecture my staff every day and try to get them to take a helicopter view. I challenge them most of the time and encourage them to think.

Another leader, the managing partner of a quantity surveying consultancy firm, highlighted the need for customer care in the construction industry and stated his desire for his followers to be sensitive to the needs of the clients they serve; this had brought benefits to the firm. He noted:

> I want to have a few more like me. I want my employees to have a caring attitude. We get jobs not because we are the best quantity surveying firm in town. It’s because we care for people and our clients. I think it’s a matter of trust that we have built up over the years. It keeps bringing us jobs.

Whereas all the leaders interviewed were concerned about mentoring their followers, a few specifically expressed their intention and active effort to find suitable successors to take over the reins of the organization from them. One of them said:

> I would like my employees to go further in their jobs. I hope to mentor my juniors and wish that that the organization has a succession plan for others to take over my position. My current emphasis is on mentoring and skill development of those I lead. And I want to train the first liners and second liners in my organization to take over the leadership role in the future.

CHANGES IN THE ORGANIZATIONS

The leaders interviewed expressed their desire to bring about certain changes into their organizations. Describing their aspirations for the future of their organizations, some leaders said that they wanted to bring more professionalism into their organizations so that they can contribute more to society. A CEO of an engineering design consultancy firm noted that:

> I want it to be a very professional firm. That is whatever we do; we have to do it very professionally. My engineers understand it well. It’s tough but I want to have a clear conscience. To me, safety comes first. My clients would know that we do it professionally. We are willing to help the client but we are ready to listen to a better way. We can learn from contractors as well as suppliers. That’s a good way of learning in this competitive environment.

The managing director of a contracting company emphasized that his employees were under heavy work pressure with short deadlines, and that he wanted them to have more time to produce better output. He noted:

> I wish people are given more time to do their jobs better. There is mostly no quality of work and that is the saddest thing we face in this industry. Clients think of a project for years but they want to finish it in a day. In Singapore, there is a site meeting every week … sometimes twice a week. And this is ridiculous. Due to these deadlines and short schedules, we are taxed. I wish we get more time to accomplish quality jobs.

CHANGES IN THE CONSTRUCTION INDUSTRY

The interviewees also expressed their desire for major changes in the construction industry. Most of the leaders interviewed highlighted: the need for more professionalism in the industry; a change in the traditional conservative mindset of the industry; the need for the industry to consider adopting manufacturing processes in its operations; and the need for innovation in construction methods.

Several of the interviewees highlighted the need for professionalism in the industry as a whole. The general manager of a contracting firm also observed:

> There is an urgent need to bring about more professionalism in the industry. There is a lack of principles and professionalism in our sector. Its not only me, everyone in the industry must become a professional. And that means the pursuit of a fair and equitable outcome from the project. Most stakeholders believe that all others can make money but not the contractor. We receive the blow every time and there is little consideration in the industry. In my opinion, every player must become the professional. It can change but needs hard work. In the past, there was a healthy relationship between the designer and the contractor. But it’s not the case anymore. I hope it will change in our industry.

The president of a professional organization expressed the same concern. In his view, the construction industry was moving in a positive direction yet a lot more still needed to be done. He noted:

> I would emphasize more professionalism in the construction industry. We all have to play our roles well in our own capacities. The client must pay well, the designer must design well, and the contractor must build well. This way, people can save their costs and would not need to cut the corners. I believe the industry is improving and it’s getting better though. Yet a lot of improvement is required while some is still going on. I also think that the government plays a very important role in bringing the industry to a better position.

A senior executive in an architects’ firm expressed a desire for more effective integration of the contributions of the participants in the construction process, saying:

> I believe that there is lot of opportunity and scope for bringing synergy among various professions in the industry, and contractors. I believe that the contractors, like an architect and engineer, should also be mandated by an Act which means that you become a registered contractor. At the moment, as a contractor, your primary responsibility is the contractual responsibility. Your statutory responsibility is up to the point where you

> have built the building in accordance with the approved drawings, from the structural point of view. But you have got no other statutory liability. And in order to level up the whole profession, you really have to have some responsibility beyond that point. And only when you understand that you need to take some liability beyond that will you be prepared to change your mindset towards bringing in more professionalism into your business.

A vice president of a developer's firm put stress on innovation in the construction process and improved safety for the construction workers. He observed:

> The construction industry should adopt manufacturing processes to some degree. We need to learn from the manufacturing industry and take 30% of our construction value into the manufacturing process. We need to reduce the value of onsite manufacturing. This will improve productivity and raise the level of professionalism such that construction workers can work in premises with a roof over their heads. Everyone has a roof over his head; why not the poor construction worker? Let us do something to bring more safe and secure working conditions to the construction workers.

LEAVING A LEADERSHIP LEGACY

Some of the interviewees had not previously thought about the kind of legacies they would like to leave behind. However, many were sure about what they wanted to leave behind. The subjects of these legacies varied. Some of the leaders interviewed mentioned how they wanted to be remembered after they left the company. Most of the responses affirmed the loyalty of the leaders to their professions. A CEO of an engineering design firm said:

> For my own company, I would like to be remembered as a practical engineer. Someone who can work well with all parties involved in the project. I would like to be remembered as someone who has a heart for people and someone who can make a difference in their lives.

Similar sentiments were shared by another executive from an architectural design firm, who noted:

> I just want to be known as a good and fair architect. We are very few from [this minority group] holding key positions in architects firms in Singapore. And I wish to leave a good impression on others. Also, I want to be a good mentor, a good listener.

One director in a firm of architects was of the view that leaving individual legacies in professional corporate firms was not that easy because of the lean hierarchy. However, he emphasized the need for the establishment of systems within the firms to ensure their sustainability. He explained:

> In a practice where we have six directors, who are all very mature and level headed, I do not think we can leave our own legacies in the firm. But what we can leave behind is a structure of the organization, capable staff, and our design capability. After learning from experience and from challenges, we want to put a system in place so that we do not repeat the mistakes. However, I would like to be remembered that I left the firm in good shape.

Another executive from a developer's company put forward a vision of the desirable features of the properties his firm was developing. He reflected:

> We started with laying bricks to build small houses in Singapore. For almost 20 years, we did the same thing and laid bricks. However, the last eight years have been different. We have reached a stage where people know that our product quality is good. I hope that in next 10 years, people say that our properties are efficient to maintain and economical to operate, energy efficient, and sustainable.

The CEO of a contracting firm wanted to take more of a teaching and coaching position and transfer knowledge and skills to his followers. He also advocated the importance of market dynamics and hoped that his staff would learn these from him:

> My aim is to develop knowledgeable staff and those who can see the big picture. I want to impart to them the market intelligence that is the key to success in today's market.

These legacy statements show that the leaders in the construction industry try to relate their legacy to their professions. Although they have reached the level in their firms where they undertake more managerial duties, they still consider themselves, and think, as civil engineers, architects or quantity surveyors, and want to be remembered as that as well.

DISCUSSION

The findings of this study are in line with the conclusions reached by Nash and Stevenson (2004) in their study of successful executives and professionals. They identified four components of enduring success: happiness (feelings of pleasure or contentment about one's life); achievement (accomplishments that compare favourably against similar goals others have strived for); significance (the sense that one has made a positive impact on people one cares about); and legacy (a way to establish one's values or accomplishments so as to help others to find success in future). The leaders interviewed in this study were all happy about what they were doing, and they had realized significant accomplishments in their professional lives. More importantly, they were all committed to making a positive impact on their colleagues, followers and organizations. It was clear that they were living their values and accomplishing their leadership purpose. It was also evident that the leaders interviewed were focused to live the legacies they wanted to leave behind.

The interviewees expressed their desire to develop their followers and prepare the young professionals under their wings to take up leadership roles in the future. Most of them were actively developing their followers to have the same values and motivations which had helped them (the interviewees) to become leaders and to realize many achievements. Those who were a few years away from retirement were looking for suitable successors to whom they could pass on their responsibilities and legacies. The younger ones were trying to create and live their legacies, and were finding congruence between their passions and organizational values. The interviewees also showed their concern for the sustainability and future health and success of their organizations. They wanted to leave their organizations in a strong structural and financial shape, with enviable achievements, organizations which also had strong foundations and good future prospects.

The leaders interviewed also wanted to see significant changes in the way the construction industry in Singapore operates. A common aspiration of the interviewees was a desire for a high level of professionalism in the industry. They wished to see changes in the practices, relationships and the overall culture of the construction industry in Singapore, especially its adversarial nature. Many authors elsewhere have noted that the construction industries in their countries remain conventional in their culture, and in their operations and, business strategies (see, for example, Koskela and Vrijhoef 2001). Rameezdeen (2007) asserts that the construction industry in the UK has suffered from a poor reputation among other industries. In some countries, construction is known for a high level of corruption (see, for example, Transparency International, 2006) in addition to its lack of professionalism (see, for example, Mezher and Tawil 1998). This image of the construction industry in those countries has made it unpopular to young and bright talent as a field in which to pursue their careers (Rameezdeen 2007). Thus, whereas the adversarial attitude, lack of professionalism and poor social image of the construction industry are not limited to Singapore, the response of the interviewees indicated that there is a strong desire for change among the industry's leaders in Singapore. This bodes well for the future of the construction industry in the country.

Another area which some of the leaders interviewed highlighted as needing change was that of innovation in the technologies adopted. A specific suggestion was that more of the activities on the construction site should be moved into manufacturing. Gaining more value from innovation through manufacturing would increase both productivity and safety on site. This issue has been mentioned in other studies in Singapore (see, for example, Construction 21 Steering Committee 1999), and there have been programmes to promote innovation in the industry since the mid-1980s, including policy guidance, financial incentives, awareness creation and other forms of promotion but it is evident from the interviews that there is still a long way to go. In this regard, Singapore's construction industry seems to lag behind those of some countries as some recent works show that the pace of efforts to industrialize the construction process has increased, and much progress has been made (Winch 2003; Monjo-Carrio *et al*. 2007). Thus, much more is yet to be done in the area in Singapore and the leaders expressed a desire to see progress in it.

IMPLICATIONS FOR LEADERS

There are many lessons that can be learnt from the discussion on 'leadership legacy' in this paper. Galford and Maruca (2006) note that some leaders never give a thought to their aspired leadership legacy because they are too busy in their jobs. However, it is never too late to leave a legacy or, at least, to think about it. Once the leader knows the legacy the leader would like to leave behind, it is easier to feel the worth of leadership and put in the effort to achieve the desired legacy. Brooks *et al*. (2004) observe that a leadership legacy is not something that just happens all at once. A legacy is built up moment by moment, in small activities and interactions. As mentioned above, true leaders do not only create their legacies but actually live them. A strong belief in living one's legacy can uplift the followers' spirits and inspire them to perform better. Therefore, leaders, at all stages of their careers, should give some thought to the legacy they would like to leave behind.

All leaders (and especially those who are near to retirement) should start thinking about the legacy they want to leave behind for their followers, organizations and more specifically their successors. Such contemplation of their legacies is likely to improve their performance in their positions as they would have a clearer idea of what they want to leave behind for their successors (Freeman 2004). They should also reflect upon the real legacies they have created so far during their careers, and the impact these legacies have made. If leaders articulate and communicate their legacies, that can help others to recognize the importance of those legacies, and to determine how they can keep the legacies alive. Such messages can also help the younger leaders or leaders-to-be in the organizations to start thinking about their own legacies and the impact they would like to make on their colleagues and their organizations.

Thinking about leadership legacy should be a catalyst for action and a lens through which the young leaders can see their future. They can assess their own motives and values and try to establish their consistency with organizational goals and their followers' expectations. Thinking about one's legacy also leads to a greater sense of purpose, and decisions that go beyond daily routine tasks (Maruca 2007). Thinking about what they want to leave behind and be remembered for, young leaders can take the opportunity to find a suitable environment where they can realize their dreams. George (2004) argues that doing this may take experience in several organizations before one can find the right place for creating and living one's legacy.

Thinking about leadership legacy also makes the leaders think more about what they really want to change, what difference they aspire to make, and what service they can render to society. Once they are true to what they want to achieve from their leadership and clear about what they want to leave behind, they gradually become more self-aware and self-disciplined or simply put, authentic leaders (Luthans and Avolio 2003; George and Sims 2007). Understanding their leadership legacy will inspire the young leaders to work towards their goals.

CONCLUSIONS

The leaders of the construction industry in Singapore who were interviewed for this study showed commitment to the development of their followers, and to leaving their companies in good shape after they retire. They want to leave legacies in the form of knowledgeable followers who can take the leadership role in the future. They also want to be remembered as fair and practical professionals who contributed positively towards the growth of their company and betterment of the construction industry. They also expressed their aspiration for bringing more professionalism, and a culture of healthy relationships into the construction industry. Thus, the leaders of the Singapore construction industry who were interviewed in this study seem to be in agreement with George and Sims who noted that 'the only thing you take with you is what you leave behind'(2007: 203). Good leaders are critical to the long-term well-being of an industry as their legacies shape the culture of the industry and the way it operates into the future. This puts the need for leadership development into relief.

REFERENCES

Brooks, M, Caverhill, S and Stark, J (2004) *Your leadership legacy: the difference you make in people's lives*. San Francisco: Berrett-Koehler.

Construction 21 Steering Committee (1999) *Reinventing the construction industry*. Singapore: Ministry of Manpower and Ministry of National Development.

Freeman, K W (2004) The CEO's real legacy. *Harvard Business Review*, **82**(11), 51–4.

Galford, R and Maruca, R F (2006) *Your leadership legacy: why looking toward the future will make you a better leader today*. Cambridge, MA: Harvard Business School Press.

George, B (2004) The journey to authenticity. *Leader to Leader*, **31**, 29–35.

George, B and Sims, P (2007) *True north: discover your authentic leadership*. San Francisco: Jossey-Bass.

George, W (2003) *Authentic leadership: rediscovering the secrets to creating lasting value*. San Francisco: Jossey-Bass.

Koskela, L and Vrijhoef, R (2001) Is the current theory of construction a hindrance to innovation? *Building Research & Information*, **29**(3), 197–207.

Maruca, R F (2007) Leave a legacy via career-long thinking. *Leadership*, 1 February.

Mezher, T M and Tawil, W (1998) Causes of delays in the construction industry in Lebanon. *Engineering, Construction and Architectural Management*, **5**(3), 252–60.

Monjo-Carrio, J, Oreiza, I, and Queipo de Llano, J A (2007) Integrated design and production: decision-making tools for optimal industrialization of housing construction. *In*: *Proceedings of the CIB World Building Congress, 'Construction for development'*, Cape Town, South Africa, 3317–26.

Nash, L and Stevenson, H (2004) Success that lasts. *Harvard Business Review*, **82**, 102–09

Nelson Mandela Foundation (2007) *About the Nelson Mandela Foundation: living the legacy*, available at www.nelsonmandela.org (accessed 5 June 2007).

Rameezdeen, R (2007) Image of the construction industry. *In*: *CIB priority theme – revaluing construction: A W065 'organisation and management of construction' perspective*, CIB Report, Publication 313, 76–87.

Whittington, J L, Pitts, T M, Kageler, W V and Goodwin, V L (2005) Legacy leadership: the leadership wisdom of the Apostle Paul. *The Leadership Quarterly*, **16**(5), 749–70.

Winch, G (2003) Models of manufacturing and the construction process: the genesis of re-engineering construction. *Building Research & Information*, **31**(2), 107–18.

STANDARDIZATION AND PREASSEMBLY: A DRIVER FOR PREDICTABILITY AND EFFICIENCY IN CONSTRUCTION

Wilfred M. Matipa[1] and John C. Fausset[2]

[1]*University of Central Lancashire, Faculty of Science and Technology, Department of Built Environment, Preston, Lancashire PR1 2HE, UK*
[2]*Telford Hart Associates, 71 Highgate, Kendal LA9 4ED, UK*

A construction project will only be regarded as successful if the product is delivered on the predicted date, at the required price and of the requested quality. A successful project therefore passes approval upon the professionals and craftsmen who completed the project. All too frequently though, projects are proving incapable of accomplishing these objectives. The unrelenting excuses presented for the persistent disappointments have ultimately portrayed the construction industry as being unreliable and ineffective. One construction process which periodically re-emerges is again receiving commendation from many quarters. Standardization and preassembly in the form of 'off-site manufacturing' (OSM) are seen to be a principle factor for improving construction in the 21st century. These concepts form the basis of the research, which proposes to evidence whether standardization and preassembly could drive overall product predictability and efficiency in construction. Based on primary data collected from the North West of England, the research shows that predictability and efficiency in the construction industry are achievable if standardization and preassembly are central to the construction process, and could contribute significantly to the desired level of value for money to the clientele sector of the industry.

Keywords: efficiency, off-site manufacturing, predictability, value for money.

INTRODUCTION

Standardization can be defined as extensive use of processes or procedures, products or components, in which there is regularity and repetition (Gibb 2001b). It can also be described as the optimum exploitation of standard components and designs (Groves 1998). Standardization of components is prerequisite in the manufacturing industries and if savings on assembly costs and predictability of product are to be realized, components must be completely and consistently interchangeable (Sparksman *et al.* 1999). Market forces are forcing contractors to reconsider their approach to satisfying customers' requirements; so are government policies and regulations that are promoting sustainable construction (Richards 2003). Traditional styles of construction such as bricks and mortar are being replaced with a wider application of industrialized building systems (Constructing Excellence 2004). Cycles of success and failures over the years have driven innovative methods in construction (Waskett 2001; Barker

[1] wmmatipa@uclan.ac.uk

2003). Most recent efforts consider that ‘standardization and preassembly’ have been drivers of predictability and efficiency in construction (Egan 1998). This research set out to establish the construction industry’s awareness of standardization and preassembly, generically called ‘off-site manufacturing’ (OSM), and the levels of acceptance for OSM in the North West of England. The paper assesses ‘whether standardization and preassembly could be a driver for predictability and efficiency in construction’. Using primary data on current trends on off-site manufacturing collected from the North West of England, the paper proves the argument that OSM could drive predictability and efficiency in construction.

STANDARDIZATION AND PREASSEMBLY

There is a relationship between standardization and preassembly in that they all tend to extensively use processes or procedures, products or components, in which there is regularity and repetition, hence requiring the organization and completion of a substantial proportion of a project’s final assembly work before installation in its final position (Gibb 2001a, c). Off-site manufacturing (OSM), however, is an all-inclusive process which incorporates prefabrication and preassembly. The process involves the design and manufacture of units or modules, usually remote from the work site, and their installations form the permanent works at the work site (Gibb 2001a; Sterling 2005). Following the Second World War, a series of initiatives enabled the UK construction industry to increase housing completions from just over 50 000 per annum in 1945 to a peak of over 400 000 per annum in 1968/9 (Barker 2003). However, as Uff (1997) conveys, for the next three decades the industry succumbed to perpetual problems and successive failures. Reports released in 2003 observed that annual completions had fallen below 140 000, a figure which the Housing Forum (2002) considered to be insufficient to satisfy new requirements, let alone replace the ageing housing stock. The importance of the construction industry to the UK economy is emphasized (Bourn 2001); hence there tends to be a cost–efficiency relationship between the unit cost of manufacturing an item and the number of times the unit is repeated (Gibb 1999). Volume and uniform production flows are fundamental to reduce the costs connected to product design, development and factory overheads (Davis Langdon and Everest 2004). Presently the minimum production runs for modular housing units are around 30 to 40 units (*ibid.*). However for significant economies of scale, orders around 150 units are required.

Preassembly in the UK construction industry

Whenever there is a shortage of labour or materials, innovative methods of construction materialize; conversely when supplies of labour and materials conform to demand, a reversion to traditional masonry construction ensues (Ross 2002).

Key drivers for OSM include but are not limited to:

- generic demand for better products from the marketplace (Ross 2002; Housing Forum 2002);
- the ‘perpetually cyclonic’ twin pressures of a reducing skills base and an ever increasing housing demand;
- government action in terms of planning guidelines, revised Building Regulations and a move towards more sustainable building techniques have combined to drive the UK house building industry into a renewed search for innovative processes and procedures, capable of achieving rapid delivery

(Parliamentary Office of Science and Technology (POST), 2004; Sterling 2005).

It is envisaged that some of the benefits of OSM could be, but not are limited to: reduced on-site time; greater cost predictability; reduced downstream costs; improved the technical performance of the final product through dependable and reliable quality and thereby reduced defects and the amounts of rework; a reduction in waste; improved project safety and health; use of new and sustainable materials, which are designed to improved and specific technical and functional standards (Gibb 2001a; Gibb 2000; Gann 2003; Sparkman *et al.* 1999). In order to increase construction efficiency, reduce overruns and improve overall quality of constructed facilities, it is vital to use faster and more efficient construction procedures such as OSM (Delves *et al.* 2001; Gibb 2001a). Cost savings could also be realized – reduced site logistics and 'site set-up' costs, rather than in the individual costs of the prefabricated units (*ibid*.). Broyd (2001) claims that prefabrication alongside site modelling tend to improve the health and safety of the workplace because factory-based manufacturing has more rigorous safety procedures. There are several obstacles preventing the uptake of OSM: the costs of setting up a construction factory and training the workforce; companies' investments in factories are not guaranteed a constant supply of projects, because it is difficult to predict the market dynamics; and there is a the preconceived idea that OSM is 5% to 12.5% more expensive than traditional construction processes.

RESEARCH METHOD

The selection of the appropriate research method was determined by the accessibility to primary data (Fellows and Liu 2003). A questionnaire survey was adopted as a primary data collection tool because of: (1) limited time; (2) reduced costs; (3) improved practicality; and (4) increased level of reliability and validity of the research data. Primary data were essential for testing the hypothesis (H_a) that 'standardization and preassembly could be a driver for efficiency and predictability in construction'; challenging 'null' hypothesis (H_o) that 'standardization and preassembly cannot be a driver for efficiency and predictability in construction'. For this research, a qualitative approach was presumed enough for the research problem at hand.

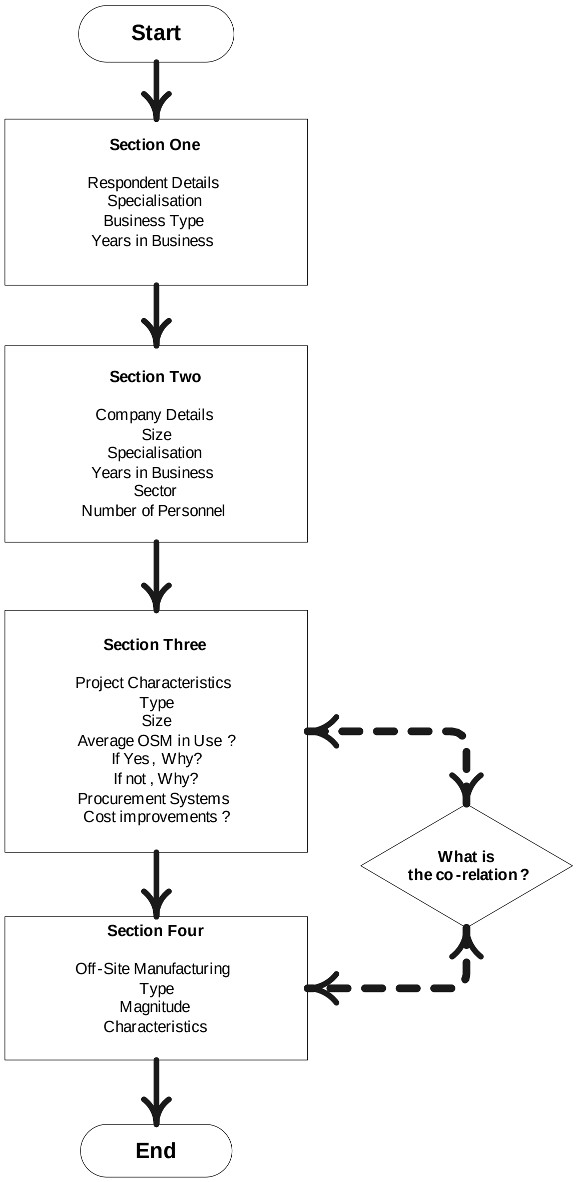


Figure 1: Questionnaire sequence model

The questionnaire for this research programme

The questionnaire had four sections, as shown in Figure 1. Section one covered personal and company details; this facilitated categorization of both the respondents and their companies. Sequentially the data were linked to section two which comprised company characteristics such as size and industrial sector. Before respondents were sent questionnaires, it was important to create a sample of the population. The principal objective of sampling is to provide a practical means of collecting and processing data representing the population under study. Any subset of observations from a population can be characterized as a sample (Witte and Witte 1998). The survey represented several sectors of the construction industry including architects, civil engineers, cost consultants, designers, housing associations, housing developers, main contractors, OSM manufacturers, quantity surveyors, structural engineers, subcontractors and town/city councils. Ninety companies from the North West of England had been sampled, using a simple fish-bow technique. Table 1 shows a breakdown of the questionnaires administered and the type of responses obtained.

The primary data collection exercise yielded a 66% response rate; out of a total number of 90 questionnaires administered, 59 were positive responses. Respondents could be further broken down into main contractors at 47%; private housing sector at 27%; education at 17%; civil engineering at13.6%; social housing and hotels 12%; industrial construction at 10%; retail at 5%, and health at 3% However, this is to be expected because OSM largely affects firms that actively implement construction such as contractors. There was no response from the architectural sub-sector; hence their view of this subject is not omitted for the sake of it, but rather, for the lack of response.

DATA PRESENTATION AND ANALYSIS

The presentation of research data and subsequent analysis follows the questioning format as modelled on the questionnaire sequence in Figure 1. This system has been adopted so as to improve the readability and comprehensibility of the research.

Incorporating standardization, preassembly, off-site manufacturing

The objective of this question was to determine whether any specific sector of the industry has accepted OSM procedures more actively than others. In the survey 70% of the responding companies claim to have used OSM in their projects, 31% responded negatively. Councils and housing associations are the only sector to display less use of OSM than recognition. The benefits derivable through the regular use and the economy of scale cannot be determined from this question alone; correlation between several of the following questions was required. Additional data suggested that OSM is becoming established across the industry and especially so in the main contractor and housing sector. This means that improvements and innovations in construction procedures have not only made the incorporation of the OSM elements easier, but the components are far more readily available.

Principal method of OSM used

The objective of this question was to ascertain the frequency of OSM used and if the implementation was restricted to particular sectors of the industry. The two most popular forms of OSM systems are framing at 20% and structurally insulated panels at 16.6%, which conforms to generic individual sectors. Respondents also indicated that the levels of acceptance for the various OSM systems were comprehensive across the industry sectors with the exception of bathroom and kitchen pods; because typical industrial units do not require large numbers of toilets or kitchens, these elements are usually bespoke. Key factors cited included: improved cost control (12%); improved speed of construction (41%); introducing innovative systems (8%); previous experience of OSM (1%). It was also envisaged that procurement systems as well as financial mechanisms could influence the use of OSM; hence there was a section on the questionnaire covering generic procurement systems, and financial mechanisms for projects.

Assessment of procurement systems for projects that incorporate OSM

The conclusions to be drawn from this question were expected to display parallel correlation between private and public-driven procurement systems. It was observed that housing (public or private) predominantly uses traditional procurement processes, still displaying the fragmented and individualist nature of this sector of the industry as reported by Egan (1998). A possible rationale could be that clients in the housing sector control the entire project from the design and development process through to completion, employing the individual professionals for the separate tasks as and when they are required. Conversely, the larger projects, education, health, hotel and retail sectors, request the supply chain to be moderated and place the responsibility (risk) upon the contractor to complete the entire construction; which is predominantly design and build, and its variants such as private finance initiative, partnerships and so forth.

Assessment of financial mechanisms for projects that incorporate OSM

It was important to extract the difference between public funded projects and private financed ones so as to establish the influence funding could have on OSM. Privately funded projects accounted for 45.8% of the total, which included private housing, civil engineering, retail and industrial projects. The eight publicly funded projects, in education, health and social housing signified 13.6%, i.e. the deployment of OSM was higher in privately financed projects than in the public sector. However, that is to be expected because the private sector is profit driven, hence any system that could enhance that tends to be of use. Depending on the design, the total value of OSM elements as a percentage of the overall contract value was estimated at below 20%. The highest volume of OSM elements used in the survey were framing systems and structurally insulated panels, representing 37% of the total. The elements in the structure of buildings that these two elements supplement or replace are the ‘internal walls’. These elements were revealed in the Building Cost Information Service (BCIS) survey (2004) to make up approximately 18% of the project total costs. Therefore, it is considered it would be difficult for most projects to achieve above the 20% boundary limit.

Assessment of predictability and efficiency for projects that incorporate OSM

Sinclair (1992) defines ‘predictability’ as, ‘happening as expected’ or ‘happening or turning out in the way that might have been expected or predicted’ and ‘efficiency’ is identified as, ‘competent, having the ability to do something well or achieve a desired result without wasted energy or effort’. When applied to OSM ‘predictability’ is referred to as completing the project at the desired cost and ‘efficiency’ is realizing maximum employment of the resources, labour and material, reducing both project duration and waste. Using a quantitative ordinal data scale (Fellows and Liu 2003) respondents were asked to rate predictability and efficiency of projects that incorporate OSM. The rating to the responses ranks the dataset, in terms of being larger/smaller, the same, greater/lesser, assigning an order (rating) for the choices (Holt 1998). Processing research data using this format is beneficial for observing correlation between sub-sets or testing the hypothesis (*ibid.*). Five responses were obtained: (1) ‘significantly increases’ project predictability; (2) ‘slightly increases’ project predictability; (3) ‘no discernible difference’ to project predictability; (4) ‘slightly reduces’ project predictability; (5) ‘significantly’ reduces project predictability. To evaluate the appropriateness of OSM it was prudent to monitor changes that could result from deploying OSM on projects using the BCIS (2005) survey of construction projects completed between 1998 and 2002, which indicated that: (1) 60% of projects overran by a mean of 16% on project duration; and (2) 53% displayed a mean discrepancy of 20% on project cost overrun.

The findings of secondary data compilation revealed the mean of the OSM case studies to be overall 6 1 percents on total project/budget cost. The ‘initial costs’ of OSM projects over a similar sized traditionally constructed building were 4% above traditional costs; over the project period, the median was a 22% reduction in project duration, and the mean at 17% decrease in project duration. Producing OSM projects consistently create such savings: projects achieving a 15% (16% – 61%) improvement on project cost predictability is 'significant'. Similarly if OSM projects consistently produce a 20% (+20% to 17%) improvement in project duration, they must also be considered 'significant'. Table 1 summarizes the ratings of various facets of the questionnaire by respondents. The table shows a matrix of how respondents rated various aspects of OSM under key sub-headings such as project predictability, project quality, project health and safety, project efficiency, project duration, project costs and environmental impact. It is from these ratings that data were obtainable to test the research hypothesis. Additionally, the qualitative findings from the survey demonstrated that 59% of the respondents thought incorporating OSM improves the project quality by some; while 53% of the respondents believe OSM improves project health and safety; and 65% of the respondents believe OSM improves the environmental impact of construction. Before testing the hypothesis, it was prudent to evaluate the correlation of sections of the questionnaire. Two pairs of questions were provided: question 13 reflected on project predictability; question 16 was concerned with project efficiency question; question 17 project duration and question 18 considered project costs. The intent was to present data that qualify OSM as offering predictability and efficiency in construction.

Using correlation tests it was possible to determine whether two variable sets of data (predictability and efficiency) are related. This entailed identifying a tendency for pairs of observations to occupy similar relative positions in their respective distributions. Additionally before correlation can be detected, the trends or observations require the same distribution of numbers, i.e. from highest to lowest, or as in this instance, a rating system of most acceptable to least acceptable answer (Witte and Witte 1997). There are three forms of relationship: 'positive relationship': the pairs of observations display a predisposition to occupy similar relative positions; 'negative relationships': occupy dissimilar or opposing positions in their respective distributions; 'no relationship': occurs when there is neither positive nor negative similarity. Once a relationship has been established, it can be interpreted for predictive purposes by means of either a 'scatter plot chart', or a measure known as a correlation coefficient.

Table 1: Summary of ratings from respondents

Compilation of the ratings	**Predictability**	**Project quality**	**Health and safety**	**Project efficiency**	**Project duration**	**Project costs**	**Environment**	**Median of the responses to questions**
Rating 'No. 1'	19	27	25	24	30	21	27	24.7
Rating 'No. 2'	21	8	27	23	19	15	23	19.4
Rating 'No. 3'	17	18	6	10	8	16	6	11.6
Rating 'No. 4'	2	6	1	1	1	5	3	2.7
Rating 'No. 5'	0	0	0	1	1	2	0	0.6
Grand total	**59**	**59**	**59**	**59**	**59**	**59**	**59**	

The Pearson correlation coefficient, ***r*****,** is a number between minus one (–1) and one (1) which defines the relationship between pairs of quantitative variables (numbered observations) (Witte and Witte 1997). The sign of *r* indicates the type of linear relationship, whether positive or negative (*ibid.*) and the value of *r* without regard to sign, indicates the strength of the linear relationship (*ibid.*). A strong relationship between the variables is indicated by *r* being as near as possible to either (–1) or (1), i.e. variables computing a correlation coefficient of (–0.7) have a stronger (negative) correlation than variables with coefficient (0.65) (positive).

The *r* value of the regression line is (Microsoft Office Excel 2003):

$$r = \frac{n(\Sigma XY) - (\Sigma X)(\Sigma Y)}{\sqrt{[n\Sigma X^2 - (\Sigma X)^2][n\Sigma Y^2 - (\Sigma Y)^2]}}$$

The primary data from the survey could be classified as qualitative (Witte and Witte, 1997), even though the presentation is in numerical format such as percentage or correlations. Table 2 maps the coefficients for the data variables. Project predictability's lowest coefficient is with project quality, 0.71, a reasonable correlation; however its strongest coefficient is with project cost, 0.95. The correlation coefficient and therefore association between the datasets are both strong. Project efficiency's lowest coefficient is with project quality 0.67, neither strong nor weak. Conversely, its strongest relationship is with project duration 0.95, a strong association and correlation coefficient. With confirmation of the strong association between the datasets, it became prudent to test the hypothesis that 'standardization and preassembly is a driver for efficiency and predictability in construction'. The chi-square statistical test uses the concept of proof by contradiction; it uses the ordinal level data to test the frequencies. By comparing the actual or observed frequencies of the variables against frequencies without any form of relationship it creates the 'null hypothesis test' (Ott 1998).

Table 2: Pearson correlation coefficient, *r*, for data variables

Pearson correlation coefficient	**Predictability**	**Project quality**	**Health and safety**	**Project efficiency**	**Project duration**	**Project costs**	**Environment**
Predictability		0.7094	0.8545	0.9190	0.8190	0.9530	0.8290
Project quality	0.7094		0.5481	0.6662	0.7746	0.8758	0.6511
Health and safety	0.8545	0.5481		0.9833	0.9302	0.8456	0.9838
Project efficiency	0.9190	0.6662	0.9833		0.9562	0.9225	0.9768
Project duration	0.8190	0.7746	0.9302	0.9562		0.9099	0.9727
Project costs	0.9530	0.8758	0.8456	0.9225	0.9099		0.8743
Environment	0.8290	0.6511	0.9838	0.9768	0.9727	0.8743	

The null hypothesis is denoted by H_o; and the 'research hypothesis' (also called the alternative hypothesis) is denoted H_a. The hypothesis H_a for the paper is: 'standardization and preassembly is a driver for efficiency and predictability in construction'. The opposing null hypothesis H_o is: 'standardization and preassembly is not a driver for efficiency and predictability in construction'. Using Table 2, a yardstick against which to measure the table's chi-square value can be derived, and it is possible to assess whether or not it is significant: the probability of getting a chi-square value of a minimum given size even if the variables are not related to the larger population from which our sample was drawn (Naoum 1998; Witte and Witte 1997), that is, how much larger than 0 (the absolute chi square value of the null hypothesis). Table 2's chi-square value must be established before we can confidently reject the null hypothesis. The probability sought depends in part on the degrees of freedom of the table from which our chi-square value is derived, which, mechanically is a table's degrees of freedom (df) expressed as: df = (r–1)(c–1). The datasets for the questions were placed into the table, presenting the following statements: 'chi-square = 45.95'; '*p* is less than or equal to 0.01', which translates to 10% level of confidence. Therefore because the distribution is significant, the null hypothesis H_o can be rejected. The hypothesis H_a is true. 'Standardization and preassembly is a driver for predictability and efficiency construction.' It is important to note that owing to lack of space, it is not possible to include the theory of chi-square testing in this paper.

CONCLUSIONS

The research shows that even though there are modest improvements in the deployment of OSM, more needs to be done if the construction industry is to continue improving efficiency during the production phase of its products; more so presently due to the buoyancy of the industry. It can also be observed that crucial project success/failure factors such as cost, time, health and safety, the environment and quality can impact on each other positively or otherwise; hence any technique that could improve any of the factors is worth pursuing. It is important to note that value for money can be achieved not only by using OSM in isolation, but from using other methods. Further research in the views of architects on this subject would be valuable to OSM.

REFERENCES

BCIS (2004) *Time and cost predictability of construction projects: analysis of UK performance*, RICS Technical Report, August 2004. London: Royal Institution of Chartered Surveyors.

BCIS (2005) *Time and cost predictability of construction projects.* London: Royal Institution of Chartered Surveyors.

Bourn, J (2001) *Modernizing construction*, National Audit Office Report. London: The Stationery Office.

Broyd, T (2001) *Foresight: constructing the future.* Built Environment and Transport Panel Construction Associate Programme, Department of Trade and Industry.

Constructing Excellence (2004) *Innovation case history Ballenger Way Kidlington Oxon 'Modular house demonstration shows cost the only barrier'*, Case Study Ref. No. 259. London: The Housing Forum.

Davis, Langdon and Everest (2004) *Cost models of offsite manufacturing October 2004.*

Delves, A, Drayton, R and Sheehan, T (2001) *Faster construction on site: by selection of methods and materials.* London: CIRIA.

Egan, J (1998) *Rethinking construction,* Construction Task Force Report for Department of the Environment, Transport and the Regions. London: HMSO.

Fellows, R and Liu, A (2003) *Research methods for construction*. 2ed. Oxford: Blackwell Science.

Gann, D (2003) *Rethinking construction demonstrations report July 2003: demonstrating success through rethinking construction.* London: Constructing Excellence.

Gibb, A G F (2001a) *Off-site fabrication–prefabrication–pre-assembly-modularization (Parts 1 to 9).* Caithness: Whittles Publishing.

Gibb, A G F (2001b) Standardization and preassembly: distinguishing myth from reality using case study research. *Construction Management and Economics*, **19**, 307–15.

Gibb, A G F (2001c) Standardization and customization in construction: a review of recent and current industry and research initiatives on standardization and customization in construction. Crisp Consultancy Commission – 00/20.

Holt, G (1998) *A guide to successful dissertation study for students of the built environment.* 2ed. The Built Environment Research Unit, University of Wolverhampton.

Housing Forum (2002) *Homing in on excellence*. London: The Housing Forum.

Naoum, S G (1998) *Dissertation research and writing for construction students* (2004 reprint). Oxford: Elsevier Butterworth Heinemann.

Ott, L (1998) *An introduction to statistical methods and data analysis*. 3ed. Boston: PWS-Kent Publishing Co. Ltd.

POST (2003) *Modern methods of house building*, Dec. 2003, No. 209. London: Parliamentary Office of Science and Technology.

Ross, K (2002) *Non-traditional housing in the UK: a brief review*, Report for the Council of Mortgage Lenders. London: Building Research Establishment.

Sinclair, J (Ed.) (1992) *Collins COBUILD English grammar.* Glasgow: Harper Collins.

Sparksman *et al*. (1999) *Standardization and pre-assembly: adding value to construction projects*, Report 176. London: CIRIA.

Sterling, R (2005) Liverpool stands united. *Contract Journal*.

Uff, J (1997) *Contemporary issues in construction law, volume 2, construction contract reform: a plea for sanity*. London: Construction Law Press.

Waskett, P (2001) *DTI construction directorate project report current practice and potential uses of prefabrication*, Project Report No. 203032. Watford: BRE.

Witte, R S and Witte, J S (1997) S*tatistics.* Orlando: Harcourt Brace and Company.

INTERFACE PROBLEMS WITH VOLUMETRIC PREFABRICATION

Ali Danby[1] and Noel Painting[2]

[1]Unite Modular Solutions Ltd, Brunel Way, Stroudwater Business Park, Stonehouse, Gloucestershire GL10 3SX, UK
[2]School of the Environment, Construction Research Team, University of Brighton, Cockcroft Building, Lewes Road, Brighton BN2 4GJ, UK

Modern methods of construction can assist the construction industry to achieve higher levels of production and a higher quality of product. They are being promoted by the UK government and are seen by some as a panacea to the ills of the construction industry. Prefabrication does however need to be integrated with more traditional methods of construction and this interface is often problematic. The aim of this work is to identify these interfaces and to facilitate an understanding of how problems arise. The research included interviews with team members from a key prefabrication provider and selective questionnaires from contractors managing (and not managing) projects using elements of prefabrication. A lack of understanding between prefabrication specialists and those providing more traditionally built infrastructure was found to create problematic working relationships and good communication was found to be a key factor in successful projects. The various types of interface are mapped and then set against the parties involved and their timing within the project.

Keywords: communication, interfaces, prefabrication.

INTRODUCTION

This aim of this research is to model the characteristics of interface problems between volumetric prefabrication and traditional construction. The research comprises case studies, interviews and questionnaires leading to the identification of a timeline of common interface problems. The research was carried out in the UK and its validity must be considered within the emerging prefabrication market.

Modern methods of construction (MMC) is a term used to describe technical improvements in prefabrication, encompassing a range of on- and off-site construction methods (Parliamentary Office of Science and Technology 2003). It is moreover a term used by the Housing Corporation to embrace a variety of approaches including off-site manufacturing (OSM). Falling under this heading are volumetric construction, panellized construction, hybrid systems, sub-assemblies and components (BRE 2003).

The current severe skills shortage coupled with the short timescale demanded by clients means that demand for new construction is unlikely to be met by conventional construction techniques. It would seem that the market for prefabricated accommodation could increase dramatically over the coming years if manufacturers are able to overcome the barriers (McAllister *et al*. 2000; ODPM 2006).

[2] n.j.painting@brighton.ac.uk

The Egan Report, *Rethinking construction* (Egan 1998) provided impetus for the UK construction industry to consider the way in which it operated and specifically the opportunities that existed for improving the process and delivery of a higher value product. This raised the level of interest in prefabrication techniques and studies are underway to assess its potential.

IDENTIFICATION OF INTERFACES

To develop an understanding of interfaces between volumetric prefabrication and traditional construction a series of interviews were arranged. The bulk of interviews were with a selected modular prefabrication company. Interviewees chosen had a range of roles and responsibilities within the same company and were found to see the interfaces differently. Their roles can be categorized as: project management, construction management, manufacturing management, marketing and promotion and logistics.

A common list of interfaces was first established from initial pilot interviews. This list of interfaces was then given to each respondent with space for other interfaces to be added.

Table 1: List of common interfaces

Number	Process	Number	Process
1	Acoustic testing	34	Modular specifications
2	Ancillaries	35	Module tolerances
3	Arrival of modules on site	36	Offer to supply
4	Authority to manufacture	37	Operations and maintenance manual
5	Bathroom pods delivery and installation	38	Outline general arrangement drawings
6	Budgetary quotation	39	Planning applications
7	Communication	40	Pre-delivery checks
8	Defect report completion on installed modules	41	Pre-start meetings
9	Demand schedule/call offs	42	Preliminary demand schedule
10	Design/project meetings	43	Progress meetings
11	Detailed architect module layout drawings	44	Project management involvement
12	Door deliveries and installation on and off site	45	Remedials
13	Electrics installation	46	Roof structure details
14	Engineering change notes	47	Scheme elevations
15	Erection schedule	48	Scheme plans
16	Final handover	49	Shipping call-offs
17	Final health and safety file	50	Shroud
18	Finished modules on site	51	Site levels surveys
19	Fire stopping	52	Site managers
20	Fixings schedule	53	Site requisitions
21	Floor layouts	54	Site returns
22	Foundation details	55	Standard reference drawings
23	Frozen general arrangement drawings	56	Technical queries
24	Frozen quotation	57	Testing
25	Getting hold of materials	58	The crane
26	Handover documents to re-programme doors	59	The team
27	HSB drawings	60	Timing and programming
28	Initial health and safety file	61	Transport
29	Initial inquiry	62	Variations to the contract
30	Installation	63	Weather proofing

31	Lifting equipment	64	Weekly delivery report
32	Management of lifting frames	65	Window delivery & installn. on & off site
33	Manufacturing supply risks	66	Window drawings and schedules

These added interfaces were included in the subsequent list of interfaces for later interviewees. The list given in Table 1 shows the final list of common interfaces.

These interfaces were mapped against the different respondents and it was noted whether the interfaces were internal to the organization or whether they were interfaces with external organizations (but within the project organization). The interviews demonstrated that there is limited overlapping of common interfaces between the four specialisms taking part in the interview process. This seeming lack of common understanding between the various disciplines is in itself significant.

COMMUNICATION INTERFACES ESTABLISHED FROM INTERVIEWS

Communication interface problems were frequently mentioned in the interviews – with the source being interference in the communication process. This was identified by Dainty *et al.* (2006) and shown within the linear process diagram shown here as Figure 1.

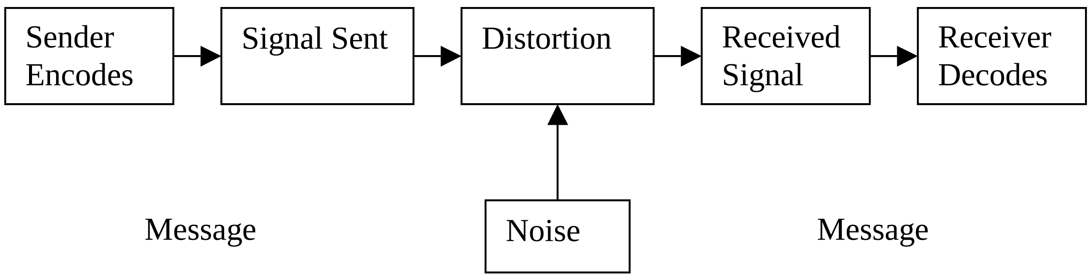


Figure 1: A model of the communication process (Dainty *et al*. 2006)

If a message, at the start of the process, is distorted due to noise (i.e. a distraction) the received signal is decoded so arrives as something different from the message sent at the start of the process.

Dainty *et al*. (2006) identified that effective communication is the key to achieving coordinated results, managing change, motivating employees and understanding the needs of the workforce. Thus improved communication is as vital to the prefabrication sector as it is in the industry as a whole.

Table 2 shows the interview responses to each individual interface both internally and externally highlighting the problems from each area from the modular supplier.

This chart shows all responses from the in-depth interviews for all interface issues both communicational and physical; as can be seen from the chart there are a wide range of interfaces for which a frequent breakdown has been established. The chart shows that there are many internal interface issues, which may highlight that the interviewees are concerned with their internal environment.

Those shaded more lightly show the links between the interfaces and external parties; those shaded darker indicate that the interface occurs within the internal environment of the business. Using the example of acoustic testing the client, principal contractor and acoustic testers are all involved within the process.

The information gathered from the interviews and questionnaires was used to establish a set of interface issues relating to the timing, communication, organizational structure, the internal and external environment and parties involved within the prefabrication process as a whole.

Table 2: Mapping interface versus respondents internal/external view

Interface problems identified involving interaction with external parties						
(Numbers indicate cumulative occurrence)	Client	Prinpl Contractor	Installer	Arch.	Struct. Eng.	Other subcontractors
Acoustic testing	1	1				1 Testers
Ancillaries	2	2	1	1		
Arrival of modules on site		3	2			2 Transport
ATMs	3	4	3			
Bathroom pods delivery and installation	4	5				3 Bathroom suppliers
Budgetary quotation				2	1	
Communication						
Defect report completion on installed modules		6				4 Remedial works
Demand schedule/call offs	5	7	4			5 Material suppliers
Design/Project meetings						
Detailed architect module layout dwigs	6			3	2	
Door deliveries & install. on & off site	7	8				
Electrics installation		9				6 Electricians
Engineering change notes						
Erection schedule		10	5			7 Scaffolders
Final handover	8	11				
Final health and safety file						
Finished modules on site		12				8 Cladders
Fire stopping	9	13				
Fixings schedule	10	14				9 Suppliers
Floor layouts	11			4		
Foundation details		15			3	10 Cladders
Frozen GA drawings	12	16	6	5		
Frozen quotation	13			6		
Getting hold of materials						
Handover docs to reprogramme doors		17				
HSB drawings						
Initial health and safety file						
Initial inquiry	14			7		
Installation	15	18	7			
Lifting equipment	16	19	8			
Management of lifting frames						
Modular specifications	17	20	9	8		
Module tolerances		21				11 Cladders
Offer to supply	18					
Operations and maint. manual						
Outline GA drawings	19					
Planning applications	20	22	10	9	4	12 All
Pre-delivery checks		23	11			
Preliminary demand schedule						
Pre-start meetings	21	24	12		5	
Project management involvement						
Progress meetings						
Remedials						
Roof structure details	22	25		10	6	
Scheme elevations	23	26	13			
Scheme plans						
Shipping call-offs	24	27	14			
Shroud	25	28	15			
Site levels surveys	26	29	16			13 Surveyors
Site managers						
Site requisitions		30				14 Material suppliers
Site returns		31				15 Transport
Standard reference drawings		32	17			

Testing						
Technical queries	27	33	18			
The crane	28	34	19			16 Crane suppliers
The team	29	35	20	11	7	17 All
Timing and programming						
Transport	30	36	21			18 Transport
UMS supply risks						
Variations to the contract	31					
Weather proofing	32	37				
Weekly delivery report	33	38	22			
Window delivery and installation on and off site		39		12		19 Window fitters& suppliers
Window drawings and schedules	34	40		13		20Window suppliers
Number of ‘external interfaces’ in which problem has been encountered	34 (52%)	40 (60%)	22 (33%)	13 (20%)	7 (11%)	20 (30%)

The percentages indicate the frequency of engagement in the problematic interfaces. The principal contractor is therefore involved with 60% of the problematic interfaces, the client with 52% the installer with 33%, other contractors such as window and transport suppliers with 30%, the architect 20% and finally the structural engineer with 11%.

Based on the findings from the interviews a questionnaire was then devised to issue to selected commercial contractors and house developers in order to gain an insight into whether the prefabricator’s perception of problems correlated with those of contractors managing the construction project. Fifteen questionnaires were circulated to selected commercial contractors and house developers of which eight responses were returned.

Open-ended and closed questions were used and a series of rating scales provided to determine frequency and severity of interface problems.

The open-ended questions enabled more qualitative responses to be provided by the contractors: ‘offsite production took the burden of repetitive works off the critical path’ and ‘the system was relatively costly, but the speed helped to reduce prelims and allowed other trades to commence early in dry conditions’.

Some negative aspects established from the respondents were that ‘it is difficult for trades up to DPC if they have not had previous experience with areas such as accuracy of bases, design detailing also needs considerable special attention, long lead in times for prefabricated components and designs have to be done a long way in advance with some designs completed late causing complications to the construction’. From this it is clear that design is (potentially) a key negative factor with the use of prefabrication. The need for early design input and for knowledge and expertise of designing for prefabrication is essential. Attitudes of respondents were however generally positive with few negative points.

Answers to the questionnaire were formatted within a matrix to include the frequency rating of the problematic interface and the severity rating of the specific interface. This matrix (Table 3) shows the frequency and severity rating of the respondent’s experiences with the interfaces. There are many overlapping interfaces where more than one respondent answered the same frequency or severity rating. From this it is clear that there are few very high frequency ratings and very few high severity ratings, suggesting that prefabrication is viewed positively by the responding contractors.

Table 3: Frequency and severity ratings of interface problems

Ref	Interface	Problem frequency rating				Severity rating				IF PARTICULAR PROBLEM OCCURS PLEASE STATE HERE
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	
1	Arrival of prefabricated modules on site	2	1 3			1 2		3		
2	Quotations from the prefabrication company	1	2 3			1	2	3		
3	Poor communication	1	2	3		1	2		3	
4	Design/project meetings			1 2 3				1 2 3		Difficult when prefabrication company is far away
5	Detailed architect module layout drawings		2 3	1			2	1 3		Designers need specialist knowledge
6	Deliveries of prefabricated components to site		2 3	1			1 2	3		Some upper floor panels arrived before ground floor
7	Erection schedule		1 2 3			1	2 3			
8	Final handover of prefabricated components		1	23			1	2 3		Clear scope of works required, who provides what
9	Health and safety files for the prefabricated components	1 3	2			1	2 3			
10	Movement of finished prefabricated components on site		2 3				2	3		
11	Fire stopping between prefabricated components and traditional construction			1 2 3			1 3	2		Careful attention/detailing required
12	Fixings schedules for the prefabricated components	1	3	2		1		2 3		Normally clear and concise
13	General arrangement drawings from the prefabrication company	1	2 3			1	2 3			Normally clear and concise
14	Handover documents for the prefabricated components	3	1 2				1 2	3		More difficult if other parties become inv
15	Installation of prefabricated components	1 3	2			1 3	2			
16	Lifting equipment for the prefabricated components	1 3		2		1	3	2		Quite easy
17	Modular specifications	1 3	2			1	2	3		
18	Tolerances for the prefabricated components	3	2	1		3	2	1		Can be very difficult
19	Offer to supply form the prefabricated company	3	2				2 3			
20	Operations and maintenance manuals for the prefabricated components	1	2 3			1 3	2			
21	Planning applications for the prefabricated components	1 3	2			1 3	2			No great problems but restrictions on design freedom
22	Involvement from the prefabrication company	1	2 3			1	2	3		
23	Remedials on the prefabricated components	1	2	3		1	2 3			
24	Reference drawings for the prefabricated components	1 3	2			1	2	3		
25	Testing of the prefabricated components	1	2	3		1	2	3		
26	Technical queries for the prefabricated components		2 3	1			2 3	1		Designers need to fully understand the system
27	The crane usage for the prefabricated components	1 3	2			1 3	2			
28	Timing and programming for the prefabricated components	1	2 3			1	2	3		
29	Transport for the prefabricated components	1 3	2			1 3	2			
30	Supply risks of the prefabricated components	1 3	2			1 3	2			
31	Variations to the contract from the prefabricated components	3	1 2			1 3	2			
32	Weather proofing of the prefabricated components	3	1 2			1 3	2			

Table 4 gives a summary of these findings in terms of the frequency they occur, their severity, and the number of contractors who identified each level.

T**able 4:** Frequency and severity rating

	Problematic frequency				Severity rating			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**

Total answers (1 + 2 + 3 + 4 = 100%)	35%	**47%**	18%	0%	34%	**40%**	25%	1%
1 Respondent	46%	34%	53%	0%	44%	53%	61%	100%
2 Respondents	54%	59%	12%	0%	56%	47%	26%	0%
3 Respondents	0%	7%	35%	0%	0%	0%	*13%*	0%
Total respondents (1 + 2 + 3 + 4 = 100%)	100%	100%	100%	0%	100%	100%	100%	100%

A problematic frequency and severity rating of 2 was the most popular choice followed in popularity by rating of 1, which means that the frequency and severity is low or infrequent for the majority of interface problems. A rating of 4 is not identified for any respondent in terms of frequency and only 1% for severity rating.

The findings from the questionnaires show that there clearly are problematic interfaces between modular and traditional construction although these interfaces carry different weightings of severity and frequency. The most frequent score was 2 which represents ‘occasional frequency’ and ‘medium severity’ ratings. These ratings are relatively low which suggests that problems are manageable and could with care be reduced to have less impact on the project.

CONCLUSIONS

This paper set out to investigate how modern methods of construction (MMC) interface with the traditional aspect of construction. The aim was ‘to model the characteristics of interface problems between volumetric and traditional construction’.

From the interviews the following key issues were identified:

- types of problematic interface;
- lack communication within prefabrication companies concerning interfaces; and
- internal and external organizational interface problems for the prefabrication company.

From the questionnaires key points established included: severity scales for each interface problem; generally positive views on working with prefabrication except where lack of experience; the importance of design detailing and advance detailing and lead-in times for the prefabricated components.

The results from these questionnaires and interviews enabled the development of an interface model incorporating parties affected, frequency of occurrence and severity involved.

This will facilitate development of a potential solution to avoid problematic interfaces occurring. It is intended that a process time mapping model be developed in order to incorporate aspects of timing, parties, predecessors to each interface and finally the severity ratings as calculated from the questionnaires. There is great scope for further research in this field. It is hoped that this research project can be continued to enable the participation of a wider sample of prefabrication companies and contractors using this model as a basic framework.

REFERENCES

Bagenholm, C, Yates, A and McAllister, I (2001) Prefabricated housing in the UK: a summary paper. *BRE Constructing the future*, Information Paper 16/01(3).

BRE (2003) *Modern methods of construction*, available at: www.bre.co.uk/housing/page (accessed 6 October 2005).

CABE (2004) *Design and modern methods of construction review*, available at www.cabe.org.uk/data/pdfs (accessed 4 October 2005).

Dainty, A and Moore, D (2006) *Communication in construction*. Taylor & Francis.

Dougan, T (2005) It's all about building what people want! *Building for a future*, 03/05, 30–32.

Egan, J (1998) *Rethinking construction*, Construction Task Force Report for Department of the Environment, Transport and the Regions. London: HMSO.

Folkes, T (2002) Factory manufacture delivers design freedom. *Building Engineer*, 08/02.

Gibb, A (1999) *Off-site fabrication*. Whittles Publishing.

Gorgolewski, M, Grubb, P and Lawson, R (2003) Off site construction can it be better for the environment? *Building for a future*.

McAllister, I and Yates, A (2000) *The use of modular building techniques for social housing in the UK: a market research report*, available at www.bre.co.uk (accessed 7 October 2005).

Neale, R, Price, A. and Sher, W (1993) *Prefabricated modules in construction.* The Chartered Institute of Building.

ODPM (2006) *Housing overview*, available at www.odpm.gov.uk (accessed 11 January 2006).

Parliamentary Office of Science and Technology (2003) *Modern methods of house building*. Post note, available at www.parliament.uk/post (accessed 7 November 2005).

EVALUATING THE IMPACT OF MULTI-SKILLING ON UK'S CONSTRUCTION AND BUILDING SERVICES SECTOR

O A K'Akumu,[1] A Blyth and B Jones

Property and Construction, University of Westminster, School of Architecture and the Built Environment (SABE), 35 Marylebone Road, London NW1 5LS, UK

Evidence seems to suggest that multi-skilling is a tentative redress for ameliorating skills crisis in a construction and building services industry. A 43-year time series data on 23 manpower attributes were evaluated as part of a research effort. The developed linear regression models show that the concept of multi-skilling obeys the 'law of diminishing returns'. That is, a weak relation was found between construction output and three or more combination of manpower attributes. An optimization model is prescribed for traditional trades**.**

Keywords: multi-skilling, law of diminishing returns, manpower attributes, optimization model.

INTRODUCTION

The decline in the number of entrant trainees, low trainee and employee retention, and increasing demand for construction products and services are today considered the greatest challenges facing sustainable construction in the UK (Olomolaiye *et al*. 2005; Ejohwomu *et al.* 2006a; *Construction News* 2006). Simply put, the UK's construction sector is skills proficiency deficient. The implication of which is a threat to global competitiveness, reliance on informal labour market and client dissatisfaction (Ejohwomu *et al*. 2006b; Leitch 2006). Thus, it should be safe to argue that the skills crisis within the construction sector is somewhat peculiar to service industrialized nations such as the UK and US, and not naturally endowed transition economies like India and China – an argument that is complimentary of an earlier investigation (Carley *et al*. 2003).

To this end, skills deficiency redress strategies in the UK have been focused on trainee management strategies; investment in people initiative; the new deal employment scheme; greater use of prefabrication; and the push for a demand led framework (Dainty *et al*. 2005; Olomolaiye *et al*. 2005). Comparatively, construction firms in the US particularly, in addition to the aforementioned redress strategies, have been exploring the concept of multi-skilling as an alternative workforce strategy for the skills crisis. This is a situation where workers breadth of skills crosses a number trades (Carley *et al*. 2003).

With emphasis on multi-skilling, prior research in non-construction industries shows significant benefits can be gained from utilizing a multi-skilled workforce. That is, there is a significant correlation between adopting the concept of multi-skilling and

[1] o.kakumu@wmin.ac.uk

proficiency in skills supply strategy (Alster 1989; Denton 1992); by training workers in more than one job, a workforce is more likely to support labour-saving technical progress (Carmichael and Macleod 1993). Also, more construction-focused studies by Burleson (1997, 1998) argue that the benefits of multi-skilling includes a potential 5–20% reduction in construction costs, a 35% reduction in required workforce and a 45% increase in average employment duration.

Regardless of some of its drawbacks: trainee capability and resistance to change (Park 1996; IRS Employment Review 1996), anecdotal evidence purports that the concept of multi-skilling is a tentative redress for the UK’s skills proficiency deficit. Therefore, whilst taking onboard the consequences of varying organizational practices (Xiao and Proverbs 2003), the objective of this paper therefore is to evaluate the impact (if any) of adopting the concept of multi-skilling as an alternative redress for ameliorating the skills deficit in the UK’s construction and building services sector.

UNDERSTANDING THE FUNCTIONAL CONCEPT OF MULTISKILLING

As a prelude to understanding the functional application of the concept of multi-skilling, this section of the paper will be discussing known construction and known construction multi-skilled modelling frameworks.

Non-construction specific multi-skilling models

In an investigative study of the dimensions of multi-skilling (with particular emphasis on audiology), Johnson (1999) has argued that there are three central multi-skilling models, which are appropriate to the practice of audiology: subordinate, collateral and collateral-subordinate multi-skilling.

A subordinate model

This involves the health professional performing varieties of non-professional tasks at non-professional level of practice. For example, subordinate multi-skilling is used to train the audiology professional to perform non-clinical tasks. This is particularly beneficial to a situation where the gap lies in the educational audiologist not having readily available support personnel.

A collateral model

In a collateral multi-skiling model, professionals from other disciplines are up-skilled through cross training to perform non professional works. For example, nurses can be trained to perform pure-tone air-conduction hearing screening.

A collateral-subordinate model

In this model, support personnel of other professions are up-skilled through cross training to perform the duties of a non professional in a different section. However, regardless of the distinct peculiarity of each of the aforementioned multi-skilling model, it is commonplace in the literature that the concept of multi-skilling can best function where manpower gap(s) exist. But the flexibility/application of these models to a construction specific sector remains unascertained.

Construction-specific multi-skilling models

In an exploratory effort to quantify, at project level, the potential benefits of utilizing a multi-skilled workforce, Burleson *et al.* (1998) derived four multi-skilling modelling strategies: dual, four, four skills-helpers and theoretical maximum labour strategies.

A dual skill labour strategy
Burleson *et al*. (1998) argued that the dual skill labour strategy was developed as a direct extension of the traditional wave theory of project scheduling. That is, as a schedule is developed, the primary objective of a working gang will be to achieve maximum productivity whilst performing tasks – a pattern that is consistently employed whilst dealing with all allocated tasks (Coombes 1990). Drawing on this theory, it can be argued that the dual-skill concept identifies craft combinations with complimentary workloads, thus ensuring employees enjoy a prolonged employment duration by being dual-skilled.

A four skill labour strategy
A four skill strategic model is a multi-skilling framework for minimizing sets of general craft classifications. In order words, if the skills requirement for executing a particular project from its conception to completion phase is classified into four general groups, for instance, its multi-skilling factor would then be centred on four different combinations. For example, in the development of the CII model plant project, Burleson *et al*. (1998) derived these four skill craft groupings: civil/structural workers, general support workers, mechanical workers and electrical workers – a grouping that is specific to the CII model plant project.

A four skill-helpers labour strategy
This is a modification of the four skills labour strategy. However, in this case, each original craft group consists of workers from three skill levels: novice/helper, journeyman, and foreman. Although, the underlying concept of the four skill-helpers labour strategy is somewhat a direct translation of a collateral-subordinate multi-skilling model. Burleson *et al*. (1998) has argued that the theoretical basis of this strategy is dependent on factor flexibility across the project.

A theoretical maximum labour strategy
This multi-skilling model assumes that the ‘construction worker’ consists of just one craft classification system. Theoretically, all construction workers are fully multi-skilled and flexible – thus, they can be moved across any project task. In order words, functionally, a theoretical maximum labour strategy identifies a maximum to the benefits of multi-skilled craft utilization (Burleson *et al*. 1998).

PRESENTATION AND ANALYSIS OF DATA

The study data – a 43-year time series, which is secondary – was harnessed following a literature review and questionnaire survey (semi-structured) of, the supply and demand for construction and building services skills in the Black Country (Olomolaiye *et al*. 2005; Ejohwomu *et al*. 2006b). Hence, it would be pertinent to note that the rationale for investigating this secondary information stems largely from the paucity of construction firms that completely imbibes the concept of multi-skilling. However, the suitability of the data used rests in its wholeness, that is, the annual construction statistics report (primary source of the secondary data) reliably compiles indexed information on the goings-on of the construction and building services sector.

Reliability of data

Drawing on the arguments for and against the reliability of the existing construction and building services statistics (Pearce 2003; Briscoe 2006), emphasis was placed on addressing the problems of data inconsistencies, i.e. ensuring consistency of constructs through ‘re-assignment’. In addition, data conversion software was employed during data computation to eliminate typographical and duplication errors.

Missing data
With the aid of SPSS, all missing data were coded using numerical values. Although this value simply tells the computer that there is no recorded value for a participant for a certain variable; in this study, missing values were computed using averages to particularly enhance any continuity of trend (Field 2000).

CORRELATION

Following the explorative data analysis, a measure of the linear relationship of the participating variables became imperative for robust modelling.

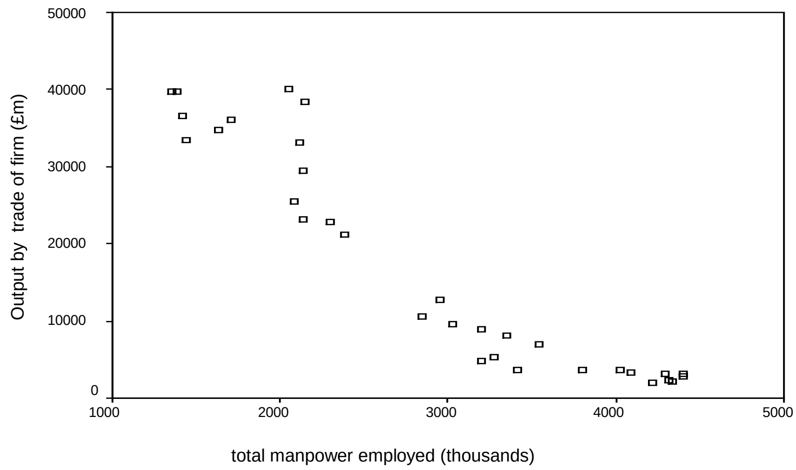


Figure 1: Scatter plot – output against TMPE

Figure 1 is a scatter plot of aggregate output and participating aggregate manpower variables. A scatter plot tells us the nature of the relationship, if any, what type of relationship it is and whether any cases are markedly different (outliers) from the others? Overall, the resulting scatter plot (Figure 1) suggests a negative linear relationship persists, that is, as output increases aggregate manpower decreases. Also, there are no obvious outliers in that most points seem to fall within the vicinity of other points. Note that a scatter plot of aggregate output against disaggregated manpower (22 independent variables) showed semblance characteristics. See Appendix 1 for 3D scatter plot of traditional and non-traditional manpower variables.

Pearson’s Correlation Coefficient (PCC)
On completing the preliminary glance at the data, correlation was conducted in SPSS using Pearson’s Correlation Coefficient (PCC). The decision to perform the PCC was informed by the nature of data (parametric) being investigated.

		Total manpowe employed Thousan operatives trade of	total value work
Total employed - operatives by trade firm	Pearson	1	-.938**
	Sig. (2-	.	.000
	N	32	32
total value of work	Pearson	-.938**	1
	Sig. (2-	.000	.
	N	32	32

**. Correlation is significant at the 0.01 level (2-

Figure 2: Correlations

Figure 2 provides a correlation for output and manpower variables. Underneath each correlation coefficient, both the significance value of the correlation and the sample size (N) on which it is based are displayed. In Figure 2, aggregate output and aggregate manpower are negatively correlated with a Pearson's Coefficient of r = -0.938 and there is a less than 0.001 probability that a correlation coefficient this big would have occurred by chance. The significance value suggests that the probability of this correlation being a 'fluke' is very low. Hence, the confidence that the relationship between manpower and output is genuine; but the correlation matrix for output and disaggregated manpower revealed an averagely high Pearson's Correlation, r. The implication of which is difficulty in fitting the data to a linear regression model given likely possibilities of multicollinearity. Therefore, as precautionary measure factor analysis, which is a data reduction technique was implored as a cushion for multicollinearity (Dunteman 1989).

EXPLORATORY MODELS

Following the successful disaggregating and identification of all underlying variables and in line with the concept of multi-skilling, eleven exploratory models were developed based on Equation 1, which is a multiple regression equation

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots\ldots\ldots\ldots\ldots + \beta_nX_n \qquad (1)$$

Where, Y = dependent variable; β_0, the intercept (constant) and $X_{1\text{-}n}$, independent variables. In other words, functionally, the dependent variable Y is the value of work done (construction output). While the independent variables from which the conceptual framework used in evaluating the concept of multi-skilling was derived (see appendix 2) are: general builders; building and civil engineering contractors; civil engineering; demolition; reinforced concrete specialist; roofers; asphalt and tar sprayers; scaffolding specialist; insulating specialist; plumbing; heating and ventilation; plastering; joiners and carpenters; flooring contractors; floor and wall tiling specialist; suspended ceiling specialist; painting; glazier; plant hirers; electrical contractors; constructional engineers; and miscellaneous.

However, it would be pertinent to note that some of the predictors in these exploratory models are accepted based on past research findings (Burleson 1997; Carley *et al.* 2003); while others were based on substantive theoretical inferences. Table 1 is a summary of the developed exploratory models showing the values of r, r^2, Durbin-Watson, p-value and full regression equations. See Appendix 2 for fuller details on the adopted skills combination framework

Table 1: Summary of developed exploratory models

Predator Variables	R	R^2	P-value	D-Watson	Model
1) Un-factored TT	0.998	0.995	0.0001	1.227	Y=1165.938 + (10.23Heating&Venti) + 14.52Joiners&Carpenters
2) Factored TT	0.963	0.928	0.0001	0.208	Y=22819.731 + (12944.45 TT)
3) 2 Step Multiskill A	0.997	0.993	0.0001	1.704	Y=747.550 + (15.66 Heating & Venti)
4) 2 Step Multiskill B	0.972	0.946	0.0001	0.169	Y=3548.792 + (40.068 Joiners &Carpenters)
5) 2 Step Multiskill C	0.925	0.857	0.0001	0.062	Y=3264.533 + (28.447 Painting)
6) 2 Step Multiskill D	0.998	0.995	0.0001	1.727	Y=1165.938 + (10.23Heating &Venti) + (14.52 Joiners&Carpenter)
7) 3 Step Multiskill A	0.997	0.993	0.0001	1.704	Y=747.550 + (15.663 Heating & Venti)
8) 3 Step Multiskill B	0.995	0.990	0.0001	0.562	Y=-5360.506 + (31.47Joiner&Carpenter) + (31.44Elec Contr) + (8.77Roofers)
9) 4 Step Multiskill A	0.998	0.995	0.0001	1.227	Y=1165.938 + (10.23 Heating& Venti) + (14.52Joiner&Carpenter)
10) 4 Step Multiskill B	0.972	0.946	0.0001	0.169	Y=3548.792 + (40.07 Joiner&Carpenter)
11) Factor TT & N_TT	0.999	0.999	0.0001	0.967	Y=22819.73 + (12944.45 TT) + (3571.94 N_TT)

* TT = Traditional Trades; N_TT = None Traditional Trades

As shown in Table 1, the eleventh model with predictor variables *factored TT and N_TT* explained the most variance in *output* (R^2 = 0.999), simply because all of the 23 manpower variables were considered. However, in reality, it would be rarity for a tradesman to be skilled in all 23 trades.

Model number five with predictor variables *painting* and *plasterers* explained the least variance in *output* (R^2 = 0.857), a finding that can be attributed to considerable poor mix of skills. Also, models one, six and nine, regardless of their different combinations of predictor variables, explained precisely the same amount of variance in *output* (R^2 = 0.995), which is a clear indication that given the ideal mixes of skills, the concept of multi-skilling can only be beneficial.

However, the overall implication of these finding is that, the concept of multi-skilling obeys the economic theory of diminishing returns. That is, as we add more units of a variable input (for example, labour) to fixed amount of construction output, the change in variance explained will first rise and then fall. Therefore, based on these analyses, the optimum number of manpower attributes is two, a finding that is complementary of the results of an earlier investigation by Gomar *et al*. (2002), wherein further research involving optimization models indicates that there is almost no marginal benefit to being semi-skilled (or greater) beyond three combinations of manpower attributes. Furthermore, the negative coefficient derived in model number eight is a clear indication that the wrong combination of skills can result to negative productivity. Note that the decision to fit the models on a linear regression was informed by the nature of variable relationship (see Figures 1 and 2). In addition to the 11 models being statistically valid (by referring to the R – squares and p-values only), conclusively, emphasis will be placed on model number 6 because it is arguably the most efficient and/or economical, as suggested by its Durbin-Watson value of 1.727.

CONCLUSIONS

The UK construction and building services sector is skills proficiency deficient. The implication of which is the threat to global competition, reliance on informal labour markets and client dissatisfaction. However, drawing on existing gaps – skills crisis – a labour utilization strategy (multi-skilling) was considered as tentative redress for efficiency in skills supply proficiency and sustainability. To this end, this paper's finding showed that multi-skilling is beneficial to the UK construction sector provided the appropriate combination of skills is used. An optimization model for implementing the concept of multi-skilling thus prescribed - Y=1165.938 + (10.23Heating &Ventilation) + (14.52 Joiners and Carpentry).

REFERENCES

Alster, N (1989) What Flexible Workers Can Do, *Fortune*, 13 February, **199**(4), 62–6.

Briscoe, G (2006) How Useful and Reliable are Construction Statistics? *Building Research and Information Journal*, **34**(3), 220–9.

Burleson, R C (1997) An Analysis of Multi-skilled Labour Strategies in Construction, PhD thesis, University of Texas at Austin, Texas.

Burleson, R C (1998) Multiskilled Labour Utilization Strategies in Construction. *Journal of Construction Engineering and Management*, **124**(6), ASCE, 480–9.

Carley, A L, Goodrum, P M and Haas, C T and Borcherding, J D (2003) Experiences With MultiSkilling Among Non-union Craft Workers in US Industrial Projects. *Engineering, Construction and Architectural Management*, **10**(6), 374–81.

Carmichael, H and Macleod, W (1993) Multiskilling Technical Change and the Japanese Firm. *The Economic Journal*, **103**(416), 142–60.

Construction News (2006) Issue Number 6948. Available online: www.cnplus.co.uk

Coombes, J (1990) *Real World Construction Scheduling*. Seattle, WA: Frontier Publishing, Seattle.

Dainty, A R J, Ison, S G and Briscoe, G H (2005). The construction labour market skills crisis: the perspective of small-medium-sized firms. *Construction Management and Economics*, **23**, 387–98.11, 275–83.

Denton, D (1992) Multi-skilled Teams Replace Old Work Systems. *HR Magazine*, September, 48–56.

Department of Trade and Industry (2005) *Construction Statistics Annual*. London: Stationery Office.

Dunteman, G E (1989) *Principal Component Analysis*. Sage university paper series on quantitative applications in the social sciences, 07-069. Newbury Park, CA: Sage.

Ejohwomu, O A, Proverbs, G D and Olomolaiye, P O (2006b) Multiskilling: a UK construction and building services perspective. *In:* Proceedings of The Association of Researchers in Construction Management (ARCOM).

Ejohwomu, O A, Proverbs, G D and Olomolaiye, P O (2006a) The UK construction industry: a review of Black Country skills demand. *In: Proceedings of The World Association of Sustainable Development (WASD) Forth International Conference*, 6–8 November, Naples, Italy.

Field, A. (2000) *Discovering Statistics Using SPSS for Windows*. London: Sage Publications.

Gomar, J, Haas, C and Morton, D (2002) Assignment and allocation of a partially multiskilled workforce. *Journal of Construction Engineering and Management*, **128**(2), 103–9.

IRS Employment Review (1996) Skills-based pay and multiskilling. *IRS Employment Review*, **605**, S5–S8.

Johnson, C E (1999) Dimensions of Multiskilling: Consideration for Educational Audiology. *Language, Speech, And Hearing Services in Schools*, **30**, 4–10.

Leitch Review of Skills (2006) Prosperity for all in the global economy – world class skills. Available online: http://www.hm-treasury.gov.uk/media/523/43/leitch_finalreport051206.pdf

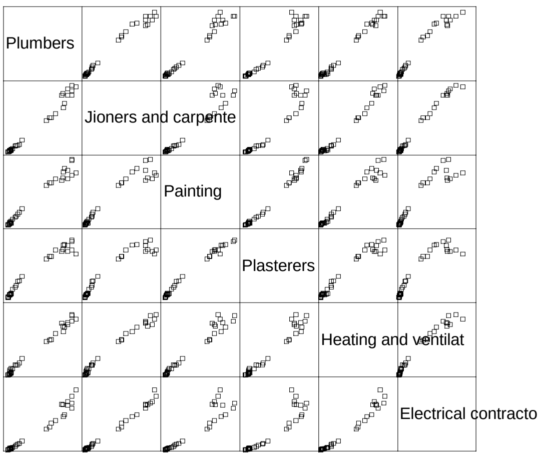
Olomolaiye, P O, Ejohwomu, O A, Proverbs, D G and Leung, M (2005) A review of construction skills supply and demand in the Black Country. A copy of this report has been uploaded on Black Country Learning Skills Council.

Pearce, D (2003) The Social and Economic Value of Construction, nCRISP, Davis Langdon Consultancy, London.

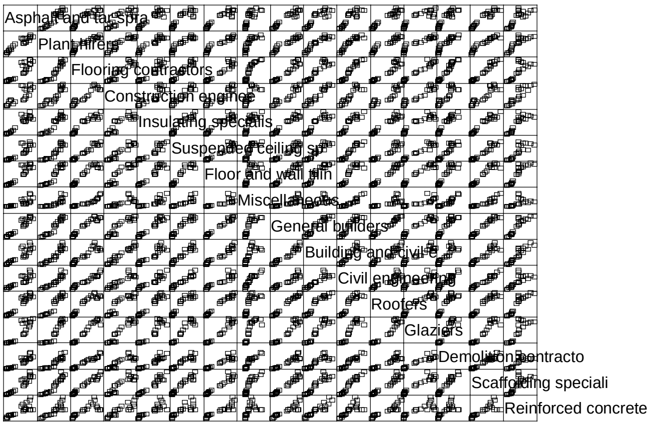
Xiao, H and Proverbs, D G (2003) Factors Influencing Contractor Performance: an international investigation. *Engineering, Construction and Architectural Management*, **10**(5), 322–32.

APPENDIX 1

Traditional manpower variables



Non-traditional manpower variables



APPENDIX 2

A conceptual frame work for evaluating the concept of multi-skilling

Traditional Trades (TT)	2 Step Skill Combination	3 Step Skill Combination	4 Step Skill Combination
1) Plumbers	1 & 6 = A	1, 6, & 7 = A	1, 6, 2 & 4 = A
2) Joiners & Carpenters	2 & 4 = B	2, 4 & 7 = B	2, 4, 3 & 5 = B
3) Painting	3 & 5 = C		
4) Roofers	2 & 6 = D		
5) Plasterers			
6) Heating & Ventilation			
7) Electrical Contractors			
Factored TT			
Un-factored TT & Others			

INVESTIGATING THE MAIN CAUSES OF VARIATION IN CONSTRUCTION PROJECTS IN DUBAI

Mohammad A Salama,[1] Paul D Gardiner and Habib A Malikappurayil

Management, Heriot Watt University, Riccarton, Edinburgh, EH14 4AS, UK

The construction industry in UAE in general and Dubai in particular has been witnessing an unprecedented boom. However, despite the readiness of financial resources as well as the active participation of multinational construction companies, the construction projects suffer from considerable variations in time and cost. The study aims at investigating the main attributes of the construction industry in Dubai in an attempt to identify the key factors that cause variations. The research comprised a set of semi-structured interviews to identify the factors followed by a questionnaire to investigate the probability of occurrence and the impact of the main factors on time and cost. The study shows that the prevalent intervention of the clients in the decision making process throughout the project lifecycle coupled with a tendency to expedite projects are the primary causes for variations in time and cost. In addition, the results reflect the gap between supply and demand in the construction sector due to the rapid growth fuelled by the needs of the fast growing economy in UAE. The study concludes with recommendations to create more awareness among stakeholders, and especially clients, of the importance of the initiation and planning phases of the project to hedge against future variations.

Keywords: construction, cost, Dubai, time, variation, client.

THE CONSTRUCTION INDUSTRY IN UAE

In UAE, the construction industry contributes almost 7.5% of non-oil GDP besides being a vital source of employment. In the first quarter of 2004, almost 6000 construction companies were registered; 2119 buildings were completed including 1,436 villas and residential complexes, 393 multi-storey commercial buildings and 290 industrial, entertainment and service buildings (Belaid and Bader 2005). With prestigious projects like Burj Al Arab (the world's tallest hotel), Ibn Batutta Mall and the Mall of the Emirates (the largest shopping centre outside North America), Dubai has succeeded in capturing the interest and attention of both construction specialists and investors in the global market. Even ordinary people strolling the streets of Dubai will assure that property prices in Dubai is guaranteed to appreciate in the range of 15–25% per annum, hence rendering the property developing firms' shares amongst the best performers in the Dubai stock exchange market. In a different context, tourists come just to cast their eyes on these landmarks. To add to the list of major upcoming mega construction projects in Dubai there are: the Palm islands (Jumeirah Palm, Deira Palm and Jebel Ali Palm), World Island, Burj Dubai (which will be the tallest tower in the world upon completion) and, finally, Dubai land, which is said to be another Disneyland but will be twice the size of it.

[1] m.a.salama@hw.ac.uk

According to a study by EFG-Hermes, an Egyptian investment bank with offices in Dubai, the real estate and construction sectors have become the centrepiece of Dubai's economy. Hanware (2005) estimated that at least $50 billion of residential projects will be built in the next four years, including at least 85,000 new homes.

In 2003, the construction industry employed 111,700 employees, which is 15% of the total employees in UAE with a soaring trend to meet the demand due to the increasing volume of construction. During the period 2000–2003, the number of employees in the construction industry in Dubai increased by 33%. Moreover, after allowing expatriates to own property in Dubai in 2002, the freehold market and the property market have witnessed a remarkable growth that has contributed to the expansion of the construction industry. The number of freehold properties is expected to double by 2009 (ASTECO 2005).

Dubai has 30,000 of the world's total 125,000 construction cranes and, as of April 2006, US$300bn worth of projects is ongoing in UAE (Gulf news 2006). Despite having such a high statistic in terms of the number of construction projects, plant and machinery, it is surprising to note that around 90–95% of construction projects witness an overrun in terms of time and money. For example, the Mall of the Emirates, a 223,000 square metre shopping centre was tendered for an amount of approximately AED 600 million and scheduled for 18 months. The final figures soared up to AED 850 million upon completion, i.e. around 38.5% increase in cost. The Dubai Police headquarters building, which is a landmark in Dubai, was tendered for a value and duration of AED 115 million and 18 months respectively. The figures at completion are 26 months and AED 147 million, which is 28% over budget and 44% over scheduled duration. The same project attracted 180 variation claims, out of which about 165 were approved.

The study aims at investigating the main factors that lead to time and cost variation in the construction industry in Dubai despite several mitigating factors that suggest the availability of both knowledge and skills: readiness of resources and active participation of multinational construction firms.

RESEARCH METHODOLOGY

The study starts with a review of the factors stated in the relevant literature both in the global construction market and in the Middle East in particular.

The research design comprised a set of seven semi-structured interviews in which experts were asked to identify the factors they perceived as the most important drivers for variation. The output of the interviews was consolidated into a questionnaire that was sent to a sample of 55 project managers out of which 23 responded, representing a response rate of 42%. The data collected are discussed in the analysis section.

The study concludes with recommendations for the Dubai construction industry based on the research findings.

Literature review

Time and cost overruns are significantly a lose-lose situation for all the stakeholders involved in the project (Eden *et al*. 2005). The increase in cost of materials due to inflation, inaccurate material estimating and the degree of project complexity results in cost overruns. Whereas, in the case of delays, amongst the important factors are design changes, poor labour productivity, inadequate planning and resource shortage (Arian and Pheng 2005). Failure to apply adequate or appropriate project management tools and techniques result in overruns, which in turn lead to rework due to the absence of quality tools and techniques essential for performance improvement (Love *et al*. 2000).

Al Momani (1996) investigated the causes of delay on 130 public projects in Jordan. The results indicate that the main causes of delay in the construction of public projects relate to project designers, user changes, weather, site conditions, late deliveries and economic conditions. Assaf (1987) investigated the main causes of delays in large building projects and their relative importance and main causes of delay that exist in Saudi Arabian construction projects. This study classified the factors according to key stakeholders' perspective: the contractors, consultants and owners. The contractors' factors included design change, preparation and approval of drawings, subcontractors' progress and payment by owners. The consultants' factors included cash problems during construction, relationships and slow decision making by owner. The owners' factors included design error, labour shortage and inadequate labour skill.

Koushki and Kartam (2004) investigated the impact of construction materials on time and cost of construction projects in Kuwait: 450 residential projects were studied. The research delved into various sub-factors that are the drivers for cost overrun due to materials. The factors included selection, availability, late delivery and price inflation during the construction. They concluded that one fourth of the projects were delayed due to late material delivery, where as price inflations accounted for project cost overrun in approximately 13% of projects.

Koushki *et al*. (2005) investigated the delays and cost increases in construction projects in Kuwait. The study stated that the three main causes of time-delays included changing orders, owners' financial constraints and owners' lack of experience in the construction business. Regarding cost overruns, the three main causes were identified as contractor-related problems, material-related problems and, once again, owners' financial constraints. The minimization of time delays and cost overruns in private residential projects would require the availability of adequate funds, allocation of sufficient time and money at the design phase, and selection of a competent consultant and a reliable contractor to carry out the work.

Salama *et al*. (2005) studied the relationship between macroeconomic factors like GDP, exchange rate, interest rate and the cost of construction in Egypt. The study emphasized the impact of the macroeconomic factors on project costs especially in periods of economic turbulence. However, these factors are not considered to be embraced in the cost estimating process explicitly.

Eden *et al*. (2005) mentioned that public projects are more prone to have massive overruns compared to other construction projects and referred to some examples: Denver Airport (cost overrun of 200%), the Danish kroner Oresund Bridge (68%) and the Scottish Parliament, which witnessed a tenfold increase in the budgeted figures.

However, other construction projects are also prone to overruns attributing these problems to factors such as poor project management practice, government polices, economic factors, and natural environmental issues (Frimpong and Oluwoye 2002).

Eden *et al.* (2000) and Ciccarelli (2004) mentioned that a major factor during the execution phase is the intervention of the client to change the scope hence altering the project's time schedule and cost. Hatush *et al*. (2005) stated that clients change the scope and requirements quite frequently without a proper recognition of the consequences thus resulting in project overrun. The study recommended freezing the design philosophies also suggested that changes should be allowed only under controlled circumstances.

Data collection

To identify the main factors that cause delay and cost overrun, semi-structured interviews were conducted with seven experts. As Dubai has a diversified and multicultural population with nearly 88% foreign population (ASTECO 2005), a diversified sample of different nationals was selected for the interview sample. The sample included representatives of the three main categories, namely the client, the consultant and the contractor with a minimum 15 years of experience in construction and an average of 25 years of experience for the whole sample. Also the sample has an average of 10 years of experience in UAE construction market covering a wide range of projects including residential, commercial and industrial buildings with values ranging from $10m–170m mostly delivered by multinational construction companies. The interviews identified 23 factors as shown in Table 1.

A questionnaire comprising these factors was sent to a sample of 55 project managers from different nationalities with an average experience of 10 years in the construction industry asking them to classify the impact of each factor on time and cost overrun as well as the probability of occurrence for each factor. The questionnaire offered two categories: low and high. In addition, the respondents had the null option if the factor under investigation had zero probability or no impact. However, this option was not chosen by any respondent. Also respondents were offered to add any factor that was not included in the questionnaire if needed.

The results based on 23 respondents were then segregated into three frequency tables for each factor. These are represented by three sets of graphs (probability, impact on time and impact on cost) as shown in Figures 1, 2 and 3. For example, Figure 1 shows the frequency and category of each factor. Factors that are perceived as of high probability of occurrence and meanwhile of high impact on time or cost will be discussed further.

Table 1: Factors leading to variation in time and cost

Factor Number	Factor Description	Factor Number	Factor description
1	Design changes	13	No proper supervision of works executing
2	Inadequate knowledge for requirements	14	Insufficient machineries
3	Inaccurate budgeting and estimating	15	Clients being developers and investors
4	No proper surveying of existing conditions	16	Fast track projects
5	Client procured materials	17	Giving relationship preference over the authority of the consultant
6	Delay in providing information	18	Insufficient time given to consultants for a complete design
7	Structural design problems discovered in the execution phase	19	The requirements are not well defined and explained for the design
8	Delay in approvals of materials	20	Scarcity of specialised subcontractor due to the high volume of construction
9	Delay in approvals of subcontractors	21	Coordination problem as more participants involved
10	Slow progress with respect to the schedule	22	Contractor evaluation not proper with respect to the construction volume
11	Inadequate skills	23	Client dominated market
12	Misinterpretation of scope		

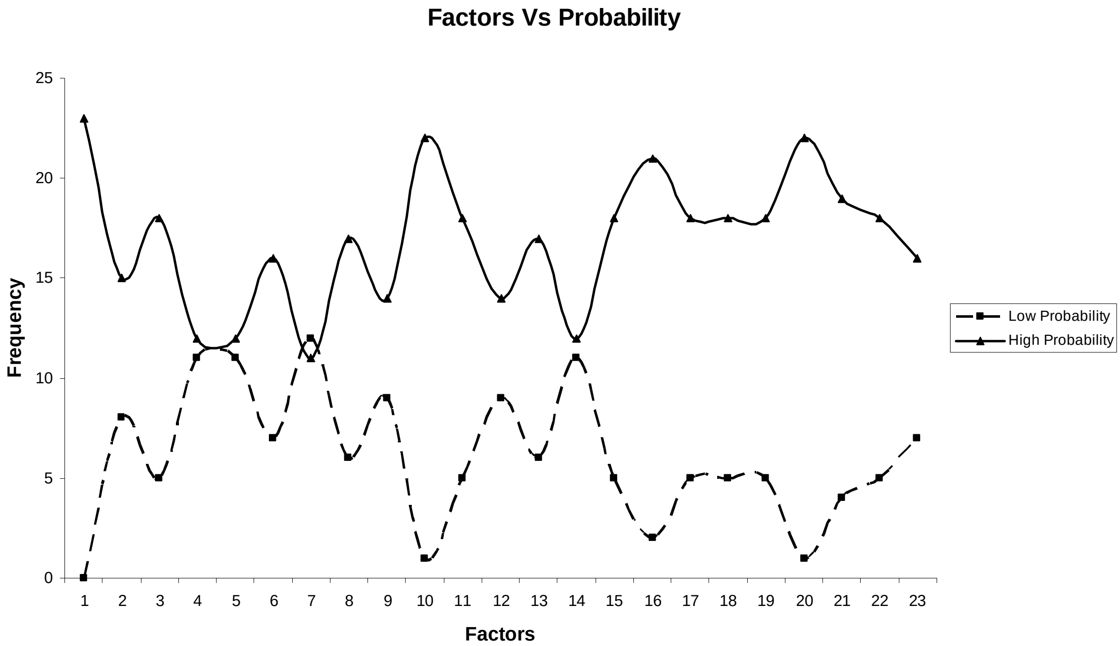


Figure 1: Factors vs. probability

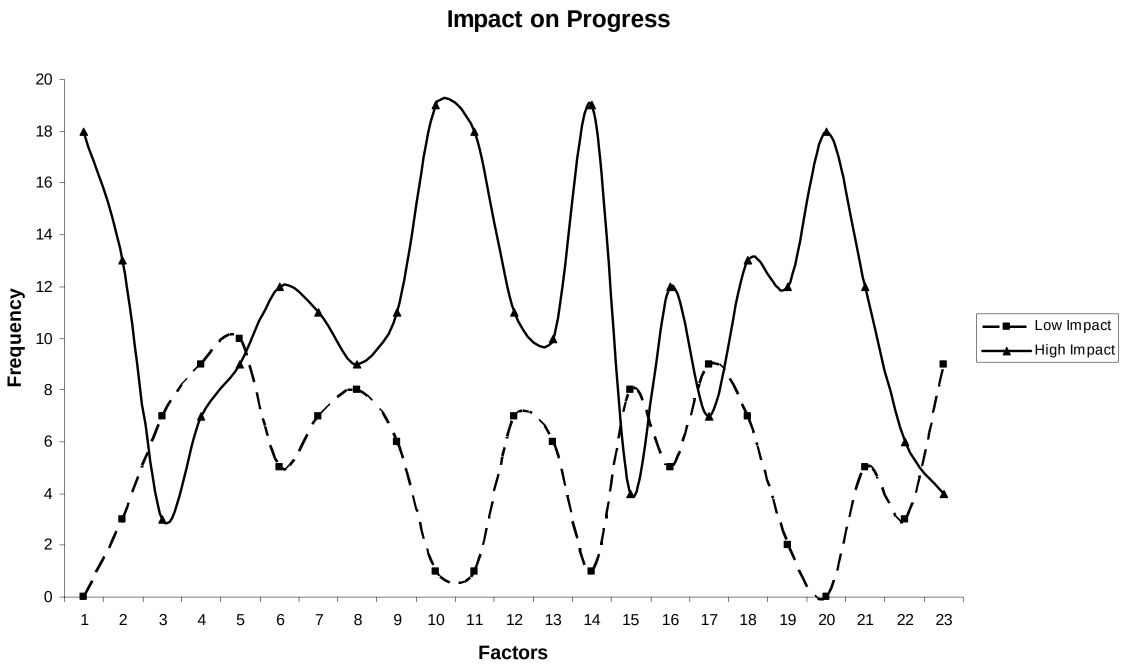


Figure 2: Impact on progress

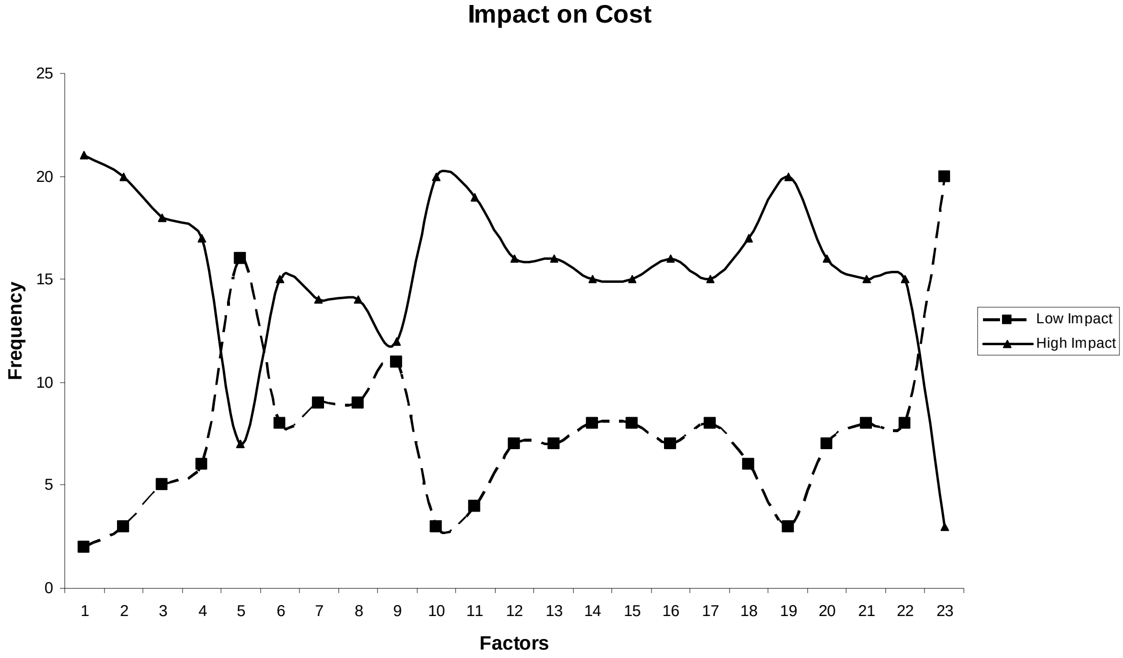


Figure 3: Impact on cost

Discussion

The results show that factors 1, 10, 16, 19 and 20 are most likely to occur. Four of these factors are interrelated. Fast track projects (16) are mostly associated with imprecision of scope (19) and design changes (1) that would slow the progress (10). Factor (20), the scarcity of specialized subcontractors, is an interesting finding that reflects a gap between the demand and supply in the construction sector in UAE in general and Dubai in particular. This gap is also manifested in factors 11, 13 and 14 reflecting the shortage in skills, and machinery.

Despite the readiness of resources, the hyper rate of development in the UAE and its implication on the construction sector has enhanced the tendency towards fast track projects. However, the industry lacks skills and machinery as the supply cannot keep up with the fast moving demand thus rendering fast track projects a risky endeavour.

The type of client has an impact on the construction industry as illustrated in factors 15 and 23. Being mostly developers and big investors, clients seek to cut costs and time simultaneously. With an annual appreciation of 15–25% in the price of property in Dubai, the rush to enter the lucrative business is another factor that widens the gap between the supply and demand in the construction market. The clients' propensity to rush the project phases is manifested in factor 18 which, when coupled with factors 2 and 4, reflects a lack of knowledge. This results in inaccurate estimates and design problems as stated in factors 3 and 7. The identified factors can be classified into three main categories:

1. Factors that occur during the initiation and planning phase – mainly to do with a lack of clear definition of the project scope, leading to changes in the execution phase resulting in variations in time and costs.
2. Factors that stem from the clients' lack of regard to the importance of each project phase. Mostly clients' market driven attitude pushes them to expedite project phases either by using a fast track approach or by squeezing the time

allocated for the initiation and planning phase as mentioned above. Clients' intervention is one of the major factors that leads to variation as previously identified in the literature review section. Clients insist on playing a leading role in the approval of design, subcontractor selection, materials and changes despite hiring a qualified project management firm thus causing delays in approvals and in many cases influences the quality of the decision made. In making decisions for the construction projects, investors in UAE often have other considerations that are not always aligned with the project management professional's approach and what is widely known as best practice. Practitioners in Dubai, for instance, report a considerable number of cases whereby the client requests additional floors to a building after the construction has started or a review of the whole design to add flats to each floor to increase profits.

3. There are external factors that inflict on the construction industry and lead to unfavourable consequences at least in the short term (manifested in a shortage of skills and machinery in general and specialised subcontractors in particular). The rapidly growing economy of the UAE is associated with a fast moving mechanism of decision making that relentlessly reviews the rules and regulations to cater for the needs of the fast growing economy. Such changes may cause a gap between the demand and supply in the construction industry (at least in the short term) as was the case when Dubai allowed expatriates to own property and moreover to boost up the property market: property owners in Dubai are allowed permanent residence in the country. The price of property in Dubai soared attracting more investors to enter the lucrative property market (ASTECO 2005). On the other hand, the fast growth of the economy is attracting expatriates from various countries in all sectors. The constantly increasing numbers of expatriates moving to Dubai maintain the demand side in the property market and keep property prices on the rise despite the construction boom. It is suggested in this paper that these conditions will prevail in the short term.

On the other hand, the results suggest that there is a lag in supply manifested by a shortage in skills, subcontractors and machinery and is identified as an important cause of the variations in projects as shown in Figures 2 and 3. These figures illustrate the impact of the different factors on time and cost respectively. The findings mostly agree with the literature emphasising the importance of the initiation and the planning phases where proactive measures can be factored in at an early stage to hedge against cost and time variations in the later stages.

The results show that clients' intervention leading to delays in approvals or drifting key decisions in favour of agendas foreign to the project and alien to the norms and best practice has unfavourable consequences on time and cost alike.

RECOMMENDATIONS

In January 2007, the financial market in Dubai made an effort to create awareness among investors to conduct adequate research before embarking on risky endeavours that jeopardise the whole stock market. The discussion above suggests the need for a similar campaign targeting the clients in the construction industry by communicating the importance of the planning phase whereby a clear scope should be identified and agreed upon by stakeholders. Also there should be a mechanism for decision making that, besides being flexible to absorb the market changes should be based on set standards and a clear definition of roles and responsibilities. This would regulate the clients' intervention and act as a safeguard against decisions that yield unfavourable ramifications. Together with an effective configuration management system from the outset, the consequences of the inevitable changes could be managed proactively.

CONCLUSIONS

The study explores the main attributes of the construction industry in Dubai in an attempt to identify the key factors that cause variations in time and cost. The results indicate that poor planning manifested in the ambiguous scope definition leads to considerable changes in the execution phase. This, together with the clients' disorganized intervention imposing decisions in such a manner that contradicts what is widely known as best practice, is among the most significant causes of variation. The results also show that there is a lack of skills and, in some cases, projects suffer shortages in machinery, which suggests a gap between the demand and supply due to the continuing growth in economy. The study draws attention to the need for effective measures to create awareness of the importance of the initiation and planning phases with emphasis on the clarity of scope and the set up of an effective configuration management system. Furthermore, the study recommends the establishment of an efficient mechanism that regulates the decision making process to hedge against any hasty decisions made by clients at the project level in response to the dynamic business environment in Dubai.

Limitations and further direction

The sample size in this study is relatively small; therefore, a further detailed study pursuing a larger sample is being undertaken. The future study will investigate the sub sectors of the construction industry in UAE, mainly the public and private sectors separately and in more depth with emphasis on the effect of delays and cost overruns on customer's satisfaction and the quantified impact on the construction industry in aggregate.

REFERENCES

Al-Momani, A H (1996) Construction cost prediction for public school buildings in Jordan. *Construction Management and Economics*, **14**(4), 311–7.

Assaf, S A (1987) Feasibility assessment of large-scale housing development in Saudi Arabia: a case study. *Construction Management and Economics*, **5**(2), 157–68.

ASTECO Property Management (2005) Why Invest in Dubai. Available online: www.astecoproperty.com.

Ciccarelli, J (2004) The Real Cost of Mitigating Delays. *AACE International Transactions*, ABI/INFORM Global, CDR11.1-9.

Eden, C, Ackermann, F and Williams, T (2005) The Amoebic Growth of Project Costs. *Project Management Journal*, **36**(1), 15–27.

Eden, C, Williams, T, Ackermann, F and Howick, S (2000) The role of feedback dynamics in disruption and delay on the nature of disruption and delay (D&D) in major projects. *Journal of the Operational Research Society*, **51**, 291–300.

Arain, F M and Pheng, L S (2005) The potential effects of variation orders on institutional building projects. *Facilities*, **23** (11/12), 496–510.

Frimpong, Y and Oluwoye, J (2003) Significant factors causing delay and cost Overruns in construction of groundwater Projects in Ghana. *Journal of Construction Research*, **4**(2) 175–86.

Fruitticher, L, Stroud, N, Laster, J and Yakhou, M (2005) Budget practice case studies. *Managerial Auditing Journal*, **20**(2), 171–8.

Gulf News (2006) Dubai has 30,000 construction cranes. Available online: http://archive.gulfnews.com/articles/06/06/18/10047703.html

Hanware, K (2005) Will Dubai's Real Estate Bubble Burst. Available online: http://www.arabnews.com/?page=6&section=0&article=61271&d=29&m=3&y=2005

Hatush, Z, Saleh, S and Shiki, A (2005) Effect of critical delay factors on cost-overrun during the design stage. *In:* F Khosrowshahi (Ed.) *21st Annual ARCOM Conference*, 7–9 September, SOAS, University of London. Association of Researchers in Construction Management, **2**, 885–92.

Koushki, P A and Kartam, N (2004)Impact of construction materials on project time and cost in Kuwait. *Engineering, Construction and Architectural Management*, **11**(2),126–32.

Koushki, P A, Al-Rashid, K and Kartam, N (2005) Delays and cost increases in the construction of private residential projects in Kuwait. *Construction Management and Economics*, **23**(3), 285–94.

Love, E, Peter, D and Li, H (2000) Quantifying the causes and costs of rework in construction. *Construction Management and Economics* **18,** 479–90.

Rettab, B and Bakheet B A (2005) Dubai Construction sector. *Sector Monitor series 03-02-01-05*, Data Management and Research Department, Dubai Chamber of Commerce and Industry, 1–27.

Salama, M, Kaka, A and Leishman, C (2005) The relationship between the performance of the economy and the cost of construction of educational buildings in Egypt: a preliminary study. *In:* F Khosrowshahi (Ed.) *21st Annual ARCOM Conference*, 7–9 September, SOAS, University of London. Association of Researchers in Construction Management, **2**, 731–40.

RISK MANAGEMENT AND ANALYSIS TOOLS FOR CONSTRUCTION SITES

Ai Lin Evelyn Teo[1]

Department of Building, National University of Singapore, Singapore 117566

Most of the monitoring tools for managing site safety used by local construction industry do not allow for the different risk levels inherent in the factors contributing to accidents on sites. These tools also do not reveal whether such deficits are critical or non-critical in warranting immediate attention. This study postulates the hypothesis that "unless the critical factors are identified and managed, a site with a high Construction Safety Index Rating may not be safe." Survey questionnaires were conducted to gather information on the construction firms in Singapore to ascertain their opinions on the factors affecting site safety. The respondents were asked to rate the degree of each factor according to the likelihood and severity of accidents into these categories: (a) 'frequent-likely', (b) 'occasional-maybe', (c) 'remote-unlikely', and (1) 'major-fatal', (2) 'moderate-permanent disability', (3) 'minor-temporary disability' respectively. Based on the research findings, the key components influencing the occurrence of accidents in relation to their likelihood and severity are determined. A model was then developed to assist the management to better manage site safety; highlighting unsafe practices basing on the likelihood and severity of accidents. This proposed model is useful as it can help the management to prioritise so that accidents can be eliminated – especially the major-fatal ones whereby precious lives can be saved.

Keywords: accidents, construction safety index, risk management, risk matrix, safety.

INTRODUCTION

In the past, there was reluctance by owners to become involved in matters related to construction safety for fear of incurring added liability exposure (Sikes *et al*. 2000). Similarly, Singapore owners also adopt the same attitude of not getting involved in safety matters for the same reason (Teo *et al*. 2004). However, since the enactment of the new Workplace Safety and Health Act (WSHA 2006), more local owners have expanded their role to proactively promote safety, as contractors are no longer solely responsible for safety; the new Act has emphasized that all stakeholders have a role to play, including owners, for construction safety. Research by Levitt and Samelson (1987) demonstrated that reducing the frequency and severity of construction injuries is the only sure way of reducing their potential liability for worker injuries. Thus, Owners must come to realize that the costs of injuries are ultimately reflected in the costs of their construction projects (Gambatese 2000).

According to Huang and Hinze (2006), the involvement of owners has been regarded as an essential requirement for the zero injuries objective and they stressed the importance of the owner's influence on construction safety. It is shown that their impact on project construction safety is significant; it was found that an important

[1] bdgteoal@nus.edu.sg

prerequisite attributed to excellent safety performance was the involvement of the owner in financially supporting the contractor's safety program as well as in the day-to-day project safety activities (Hinze 2001). In the construction accident causation model developed by Suraji *et al*. (2001), construction accidents are caused by inappropriate responses to certain constraints that emerge during the development of the project scope, in an untimely manner. According to Huang and Hinze (2006), two of the three of the owner's involvement roles are to communicate (set safety expectations) and participate (play a part in safety programme, safety observations, safety inspections, safety enforcement, and job-safety analysis).

The key to preventing accidents is through effective identification and control of risk (Peckitt and Coppin 2005). This requires performance feedback via a structured auditable assessment process. Most of the monitoring tools for managing site safety used by local construction industry do not allow for the different risk levels inherent in the factors contributing to accidents on sites. These tools also do not reveal whether such deficits are critical or non-critical in warranting immediate attention (Teo and Ling 2006).

According to Abednego and Ogunlana (2006), a good governance concept is developed to evaluate the performance by: (a) making the right decision at the right time, which is a form of active participation; (b) taking responsive, concrete action within a reasonable time framework; and (c) continuous control and monitoring, in order to achieve the goal and to prevent the risk from occurring.

As indicated by Ward *et al*. (1991), the best strategy to prevent/minimize consequences are (1) risks must be properly identified, understood and evaluated; and (2) risk should be allocated to the party with the best capability to control the events that might trigger its occurrence, in timely manner. To sustain the consequences of the risk or to prevent the risk from occurring, it depends on the best capability to control the risk. The implemented risk management strategy dealt with the consequences of the risk by problem-solving and preventive approach. Incapability to control risk properly will be reflected in absence of good safety governance thus resulting in an unsatisfactory safety performance (Flanagan and Norman 1993).

This research is conducted to ascertain the likelihood and severity of construction accidents and utilizing the findings as the foundation to develop the concept of good safety governance by providing the priorities list for immediate actions. The theoretical relationship used in this research can be summarized in Figure 1. Following the theoretical framework in Figure 1, the research is conducted to investigate the different perceptions of proper risk management. In effect, the study utilizes this knowledge to develop the good safety governance concept as a guideline for proper risk management in construction projects.

The aim of this research is to *develop an integrated safety assessment system* (ISAS) – risk management and analysis tool, by adding on to the existing tested and validated 3P + I framework (Teo *et al*. 2004) with the following proposed features:

- The proposed system is capable of prioritizing the non-compliance in the order of likelihood and severity of accidents based on their risk level.
- The proposed system can provide the identified 'consequences of non-compliance' and 'list of recommendations' for better monitoring and management of risks.

- The proposed system can identify the risk associated with the non-compliant factors and highlight the cost implication and legal implication for not complying.

Figure 1: Proposed theoretical framework

In short, the proposed *integrated safety assessment system* (ISAS) would develop a theory to contribute additional knowledge to the existing tested and validated 3P + I framework by revealing whether such deficits are critical or non-critical in warranting immediate attention and also by highlighting the consequences for failure to act (refer to Figure 2). Moreover, the proposed system can also highlight the safety measures to be undertaken by owners for (1) providing and maintaining a safe work environment; and (2) ensuring people are not exposed to hazards arising from the workplace or areas under the employer's control. This study is important because it is stipulated by the new WSHA that owners are required to take responsibility of safety standards and outcomes.

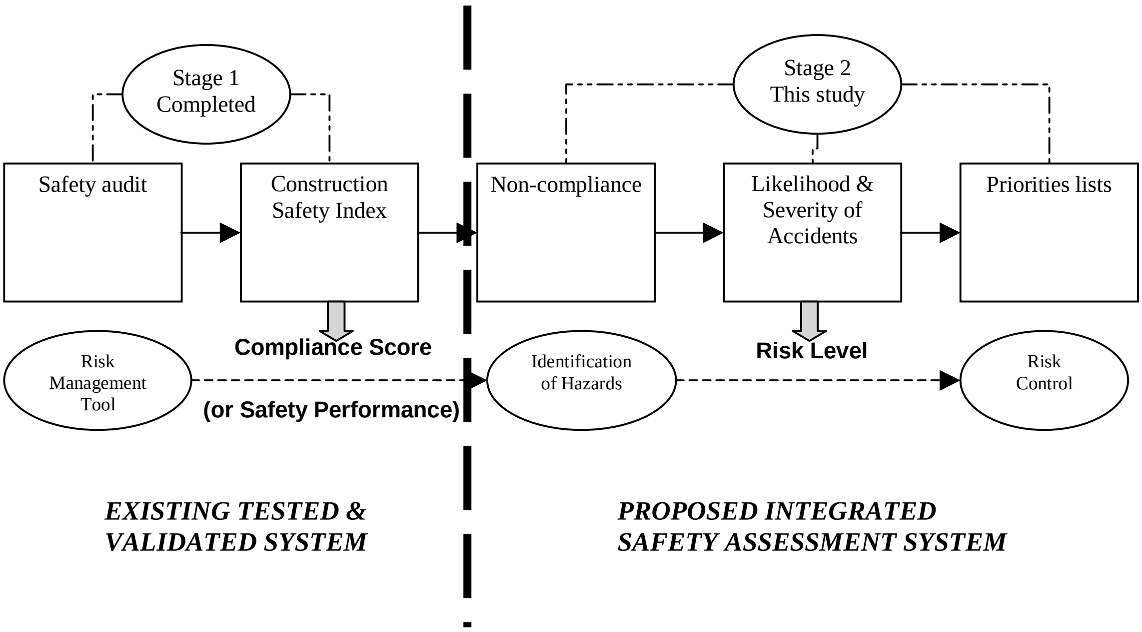


Figure 2: Stages of research

RISK ASSESSMENT AND MANAGEMENT

The safety management system (SMS) was introduced by the Singapore Ministry of Manpower (MOM) to formalize the management of site safety so that contractors are required to implement SMS to improve safety levels on site. However, effectiveness of SMS varies between sites. In response to the need of a tool to assess the effectiveness of a SMS, the 3P + I framework was developed (Teo *et al*. 2004). Based on this 3P + I framework, a Construction Safety Index (CSI), which objectively shows the safety level of the construction site (classified under four main categories namely Policy, Personnel, Process and Incentives), can be calculated (Teo *et al*. 2004). With the enactment of the WSHA in March 2006, the new Occupational Safety and Health (OSH) framework emphasizes the significance of good OSH management systems, particularly the need for comprehensive risk assessments, targeting at reducing risk at its source, with better defined liability regime. Owners, among other stakeholders under the new liability regime, have to take reasonably practicable measures to protect people affected. Moreover, companies will be required under the WSH (Risk Management) Regulations (which came into force on 1 September 2006) to conduct comprehensive risk assessments, take active steps to eliminate or minimise the identified risk and disseminate information to employees and others; as well as to comply with the Regulations, Codes of Practice and industry practices. Therefore, inserting Risk Management Regulations into the existing tested and validated 3P+I framework is vital.

One can attempt to eliminate risks, if risks are known. Nevertheless, it is impossible to eliminate all risks; some can only be reduced. When many risks exist at once or when resources are limited, the problem is knowing what risks to deal with first. This requires setting priorities (Brauer 1994) and there are several methods for doing this, such as applying quantitative or qualitative methods.

In accordance with MOM's Guidelines on Risk Assessment (MOM 2005), risk is made up of two components; namely (a) **likelihood of the occurrence** of the accident/incident or ill health taking into account the existing risk controls; and (b) the **expected severity** of a possible accident / incident or ill health originating from an identified hazard. According to Clemens and Simmons (1998), a common definition of risk for safety infers a quantitative concept; risk is the product of frequency (likelihood) and severity (consequences) of potential losses. Frequency is the probability of occurrence of an event, whereas severity is potential loss when an event occurs.

Risk assessment is an integral part of risk management, according to MOM (2005), risk assessment is a process of (a) identifying and analysing safety and health hazards associated with work; (b) assessing the risks involved and (c) prioritizing measures to control the hazards and reduce the risks. Risk assessment provides qualitative and quantitative data to decision-makers for later use in risk control. Risk assessment in the construction industry can be performed by identifying any hazardous activities or practices and evaluating the danger level (Clemens and Simmons 1998). The risk assessment matrix method is one of the commonly used methods and it is based on the risk plane concept. This is qualitative risk analysis that uses expert opinions to evaluate the probability and consequence of an event's occurrence. The risk matrix provides detailed classifications for likelihood and severity. There are several versions of risk matrix depending on the numbers of level to categorize likelihood and severity. It can be a '5 x 5', '4 x 5' or '3 x 3' risk matrix. The goal of risk management is to reduce uncertainty in describing factors that contribute to accidents, injuries and death. The aim of this research is to develop a risk management and analysis tool for helping the owners in revealing what factors contribute to accidents and injuries for administering the risk assessment and management process.

RESEARCH METHODOLOGY

This study's survey questionnaire adopted MOM's definitions. The method of collecting primary data is through a postal questionnaire targeted at the authority, the contractors and the safety consultants. The objective of the survey is to identify the significant factors in influencing site accidents from the existing tested and validated 3P+I framework with reference to MOM's definitions. The likelihood of occurrence of accident or incident can be categorised into **Remote**, **Occasional** and **Frequent** as shown in Table 1.

Table 1: Classification of likelihood of accidents used in the questionnaire

Likelihood	Description	Importance ranking in questionnaire	
Remote	Not likely to occur	Unlikely	1
Occasional	Possible or known to occur	Maybe	2
Frequent	Common or repeating occurrence	Likely	3

Similarly, the expected severity of accident or incident can be further classified into **Minor, Moderate** and **Major** to be used in the questionnaire. For the purpose of the survey in this study, modifications were made to the descriptions of moderate and major severity to make them more applicable for the study. For moderate severity, *temporary disability* was introduced to the description while for major severity; permanent *disability* was added to give better meaning to it. The modifications are illustrated in *italics* in Table 2.

Table 2: Modifications to the description of accidents' severity used in the questionnaire

Severity	Description by MOM	Modifications made to questionnaire	Importance ranking in questionnaire
Minor	No injury, injury or ill-health requiring first aid treatment only	*No injury, injury or ill-health requiring first aid treatment only	1
Moderate	Injury requiring medical treatment or ill-health leading to disability	Injury requiring medical treatment or ill-health leading to *temporary* disability	2
Major	Fatal, serious injury or life-threatening occupational disease	Fatal, serious injury *leading to permanent disability* or life-threatening occupational disease	3

* No changes were made in the survey questionnaire

The main objective of conducting surveys with the professionals is to obtain practical insights of the industry's perceptions of the risks associated with safety issues on construction sites, as opposed to theoretical studies. This will aid the development of a heuristic model to classify the factors from the existing tested and validated 3P+I framework into different risk levels. The purpose of this proposed system is to provide management with the tool that they could make use of to supplement the CSI to prioritise their attention on the significant factors influencing safety on construction sites.

The postal questionnaire comprises two main sections. The first section contains the demographic questions for the purpose of data classifications. Section two lists 114 factors extracted from the existing tested and validated 3P+I framework that could have an impact on site safety levels. The factors are divided into four categories and the number of factors contained within each category is depicted in Table 3.

Table 3: Summary of factors contained in questionnaire

Category	Number of factors
Incentive	4
Policy	13
Process	75
Personnel	22
Total	114

The respondents were asked to rate these factors according to the likelihood of accident occurrence (likely (3), maybe (2) and unlikely (1)) and the expected severity of accidents (major (3), moderate (2) and minor (1)] in their absence or non-compliance. The quantitative data collected from the survey would reveal the significant factors to be incorporated into the proposed model to allow management to exercise greater control in minimising accidents on sites.

The population for the study was 1919 contracting firms registered with Building and Construction Authority (BCA 2005). Given the size of the population, sampling was necessary for B1–C3 contractors. No sampling was necessary for the authority, the safety auditors and A1 and A2 contractors as their population sizes were small. Systematic sampling was conducted for B1, B2, C1 and C2 contractors. As the population for C3 contractors was large, simple random sampling was carried out to select 46 samples from the population of 1305 (refer to Table 4).

A total of 300 questionnaires were sent out to the respondents through mail. A cover letter explaining the purpose of the research was enclosed. To encourage response, anonymity was assured as the respondents were not required to state their name. Also, a copy of the research findings would be offered to all companies who had responded to the survey. In addition, follow-up calls were made to individual firms three weeks after the questionnaires were posted to encourage them to respond to this study.

DATA ANALYSIS

Parametric t tests and factor analysis were employed to analyse the quantitative data from the survey. The central limit theorem requires a minimum of 30 samples (n=30) for data analysis in order to achieve a normal distribution. Parametric t tests are used in the data analysis since it is assumed that the sampled data from the population follows a normal distribution. Fifty usable responses (n=50) were used for the data analysis; therefore, the distribution is assumed to be normal and a one sample t test could be applied using the Statistical Package for Social Sciences (SPSS).

The one sample t test compares the mean score of a sample with a hypothetical mean with the level of significance set at 5% ($\alpha = 0.05$). μ is fixed at 1 for ***Likelihood of Accident*** because by the definition in the rating scale lesser and/or equal to 1 is ‘accident not likely to occur’. The test hypothesis is highlighted as H_0: $\mu \leq 1$ and H_1: $\mu > 1$.

The two sample t test compares the mean score of a sample with a hypothetical mean with the level of significance set at 5% ($\alpha = 0.05$). As for ***Severity of Accident***, μ is fixed at 1 because by the definition in the rating scale equal to 1 is ‘no injury or minor injury which does not lead to disability'. The test hypothesis is highlighted as H_0: $\mu = 1$ and H_1: $\mu \neq 1$.

If the p-value is smaller than the significance level, the null hypothesis is rejected and the test result is termed significant. This implies that the variable plays a very important role in influencing safety.

RESULTS

A total of 55 professionals responded to the survey. After checking through the completed questionnaires, 50 were found to be suitable for data analysis. This yielded a response rate of 16.67%. The distribution of the questionnaires sent and the response rate for the individual categories are highlighted in Table 4.

Table 4: Population and sampling method employed in the study and the response rate

Categories	Population	Sample	Sampling method	Response Rate (%)
Authority	1	1	No sampling	0 (0.00)
*Safety auditors**	22	22	No sampling	9 (3.00)
*Contractors Grade***				
A1	33	33	No sampling	16 (5.33)
A2	22	22	No sampling	2 (0.67)
B1	50	40	Every 5^{th} on the list was excluded	5 (1.67)
B2	102	51	Every odd number on the list	6 (2.00)
C1	200	40	Every 5^{th} on the list	3 (1.00)
C2	184	45	Every 4^{th} on the list	3 (1.00)
C3	1305	46	Random sampling	6 (2.00)
	1919	**300**		**50 (16.67)**

* MOM list of approved Safety Auditors (2005) & ** BCA Contractors Registry (2005)

Of the 50 respondents, 9 were safety auditors and 41 were contractors. Generally, the respondents' average working experience in the construction industry is 14.2 years. In addition, 64% of the respondents had 10 or more years of working experience. It is expected that a certain level of accuracy in the data collected is assured.

The 114 factors were input into the SPSS software and a one sample t test was conducted to sieve off the insignificant factors. Of the 114 factors, 24 were found to be insignificant in causing site accidents (Appendix 1 of research report – see: http://courses.nus.edu.sg/course/bdgteoal/RiskManagmentTool/discuss.htm). The remaining 90 significant factors are also reflected in Appendix 1. The mean scores for the factors ranged from the 2.167 to 2.776. This suggested that they played a very important role in influencing the likelihood of accidents on construction sites.

A statistical t test of the mean was also conducted for the category concerning the severity of accidents. Of the 114 factors, 37 were found to be insignificant in so far as severity of accidents was concerned (Appendix 2 of the research report – see http://courses.nus.edu.sg/course/bdgteoal/RiskManagmentTool/appendix_2.htm). Appendix 2 also lists down the distribution of the remaining 77 significant factors. The mean scores for the significant factors ranged from the 2.191 to 2.854. This implied that if accidents involving the factors were to occur; the nature of the accidents would be severe.

The mean rating for each of the factors used in the survey were calculated using the following formula.

Mean = $\sum Y_i RAR_i / N$

Where Y = i^{th} observation

AR = Associated rating (1 or 2 or 3) and N = Total number of observations (n = 50).

As a result, a mean rating for each factor under both Likelihood of accident and Severity of accident was obtained. Applying the risk matrix assessment concept, together with the mean rating obtained from the survey; a risk management and analysis tool can be developed riding on the existing tested and validated 3P + I framework.

PROPOSED RISK MANAGEMENT AND ANALYSIS TOOL – ISAS

The findings of the survey were used to derive the risk matrix assessment system. With the severity and likelihood being established, the risk level can be determined by using the following '3 X 3' matrix. The risk level may be classified as low, medium or high and as shown in Table 5.

Table 5: '3 x 3' risk matrix

		Likelihood		
		Remote = 1	Occasional = 2	Frequent = 3
Severity	Major = 3	3 Medium Risk	6 High Risk	9 High Risk
	Moderate = 2	2 Low Risk	4 Medium Risk	6 High Risk
	Minor = 1	1 Low Risk	2 Low Risk	3 Medium Risk

Before a risk assessment model (refer to Figure 3) can be constructed, a Risk Definition Range is required. Risk Definition Range is referring to the range of value in which the risk level is determined. In order to define a range value for all the risk levels, the '3 x 3' matrix (refer to Table 5) shall be expanded into a '5 x 5' matrix (refer to Table 6) because the risk level of every non-compliant factors in this study is not an integer but any value between 1 to 9. For example, if the risk level is found to be 5.2, it will pose a problem of classification if the '3 x 3' matrix (refer to Table 5) is used. Thus, it is necessary to classify Risk Level using a range of number. Henceforth, the risk level may be classified as Low, Medium or High if the risk level is between '$1 \leq R \leq 2.5$'; '$2.5 < R \leq 5$'; and '$5 < R \leq 9$' respectively. In this way, the expanded '5 x 5' matrix (refer to Table 6) can help to draw a better distinction between High, Medium and Low Risk.

Table 6: '5 x 5' risk matrix

	1 Remote	**1.5 Rare**	**2 Occasional**	**2.5 Likely**	**3 Frequent**
3 Major	3 Medium Risk	4.5 Medium Risk	6 High Risk	7.5 High Risk	9 High Risk
2.5 Severe	2.5 Low Risk	3.75 Medium Risk	5 High Risk	6.25 High Risk	7.5 High Risk
2 Moderate	2 Low Risk	3 Medium Risk	4 Medium Risk	5 High Risk	6 High Risk
1.5 Insignificant	1.5 Low Risk	2.25 Low Risk	3 Medium Risk	3.75 Medium Risk	4.5 Medium Risk
1 Minor	1 Low Risk	1.5 Low Risk	2 Low Risk	2.5 Low Risk	3 Medium Risk

Figure 3 depicts the risk assessment module of the proposed ISAS, and the last step for risk assessment is Risk Control. The proposed ISAS (refer to Figure 4) identifies the consequences (highlights what kinds of hazards would result and what penalties would be imposed for non-compliance) and provides recommendations (refer to Table 7) for controlling risk. Expert knowledge was embedded in the proposed ISAS to assist owners in decision making when assessing risk. The proposed ISAS also provides site safety performance reports. It highlights results of all the findings of safety on sites in various formats (construction safety index report, risk evaluation report, and action plans report (consequences and recommendations)). The owners can used these reports for submission to the authority.

Table 7: Risk action

Risk level	Acceptability	Recommended action
Low Risk	Acceptable	No additional risk control measures may be needed. However, frequent review may be needed to ensure that the risk level assigned is accurate and does not increase over time.
Medium Risk	Moderate Acceptable	A careful evaluation of the hazards should be carried out to ensure that the risk level is reduced to as low as is practicable within a defined time period. Interim risk control measures, such as administrative controls, may be implemented. Management attention is required.
High Risk	Not acceptable	High Risk level must be reduced to at least Medium Risk before work commences. There should not be any interim risk control measures and risk control measures should not be overly dependent on personal protective equipment or appliances. If need be, the hazard should be eliminated before work commences. Immediate management intervention is required before work commences.

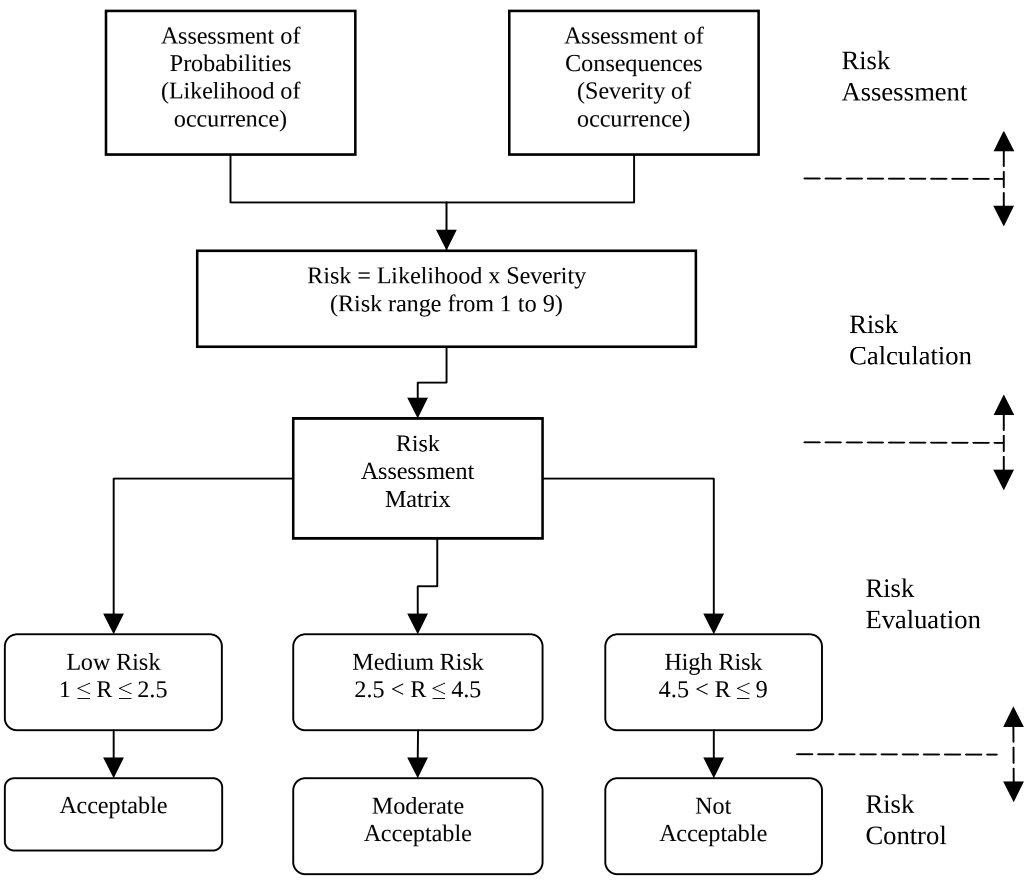


Figure 3: Proposed risk assessment model – a module of ISAS

CONCLUSION

This research has developed a theory to contribute additional knowledge to the existing tested and validated 3P + I framework by revealing whether such deficits are critical or non-critical in warranting immediate attention and also by highlighting the consequences for failure to act. Moreover, the proposed system can also highlight the safety measures to be undertaken by owners in order for them to provide and maintain a safe work environment. As it is stipulated by the new WSHA that the owners are required to take responsibility of safety standards and outcomes; the proposed risk management and analysis tool (ISAS) will be a practical tool for the owners (also can be used by other stakeholders) to conduct the risk assessment on construction sites.

The key feature of the proposed ISAS is its ability to assess risk using the risk matrix concept. The practical use of this proposed ISAS is that it provides guidelines on reasonably practicable measures for assessing and controlling risk. It adopts the enforcement strategy by using the intelligence-led monitoring approach that focuses on improving OSH performances and not simply meant for identification of non-compliance. This approach is shifting from reaction to prevention so as to enhance the risk assessment and management for construction safety. This proposed model is useful as it can help management to prioritise so that accidents can be eliminated, especially fatal ones so that precious lives can be saved.

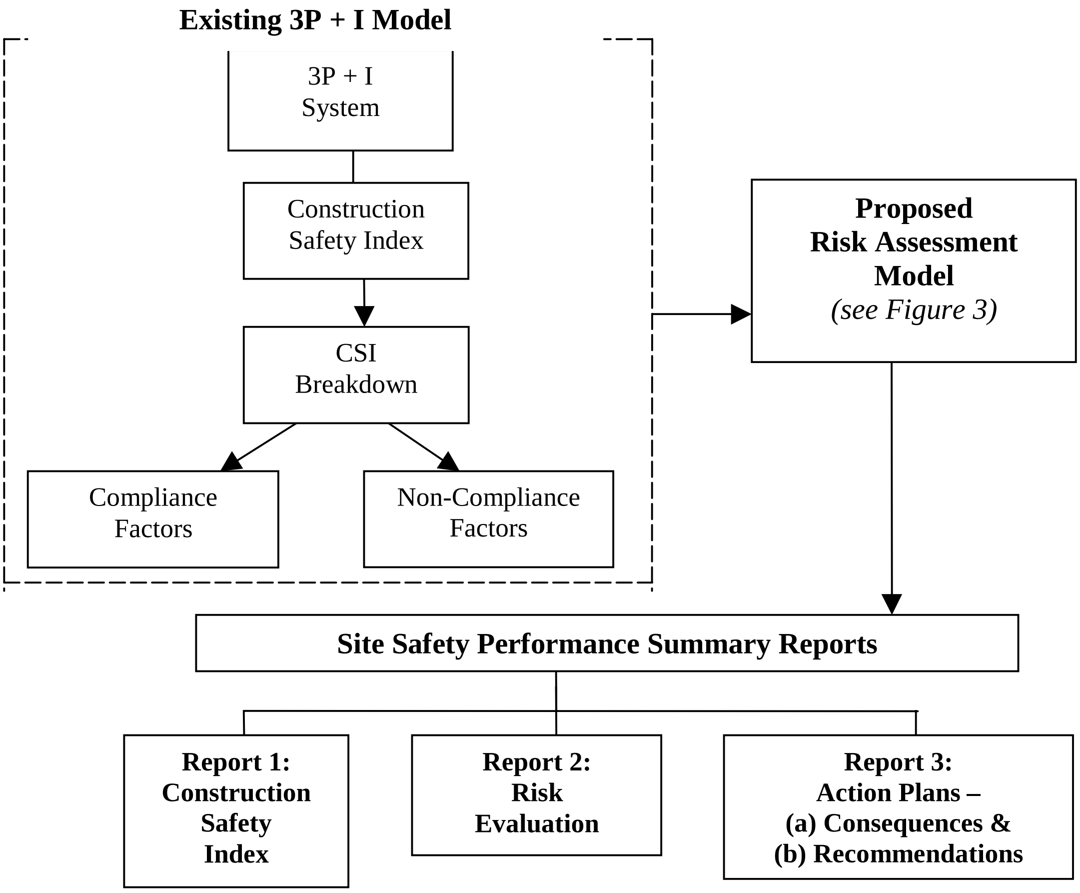


Figure 4: Proposed risk management & analysis tool – Integrated Safety Assessment System (ISAS)

ACKNOWLEDGEMENTS

The author gratefully acknowledges the National University of Singapore (R296-000-094-112) for providing funding for this research project. Ng and Pham's participation in various parts of the research project are also gratefully acknowledged.

REFERENCES

Abednego, M P and Ogunlana, S O (2006) Good project governance for proper risk allocation in public-private partnerships in Indonesia. *International Journal of Project Management*, **24**, 622–34.

Brauer, R L (1994) Risk management and assessment. *In: Safety and health for engineers.* New York: Van Nostrand Reinhold.

Building and Construction Authority (2005) *BCA contractors registry.* Singapore: BCA. Available online: http://dir.bca.gov.sg/bca/AdvSearchList.asp?actual_pg=1&ListAbsolutePage=1# (accessed 11 August 2005).

Clemens, P L and Simmons, R J (1998) Risk assessment matrix. *In: System safety and risk management: A guide for engineering educators,* Cincinnati: Dept. of Health and Human Services/Centers for Disease Control and Prevention/The National Institute for Occupational Safety and Health.

Flanagan, R and Norman, G (1993) *Risk management and construction*. Oxford: Black-well Scientific Publications.

Gambatese, J (2000) Owner involvement in construction site safety. *In: Proc. Construction Congress VI,* Orlando, Florida.

Hinze, J (2001) *Construction contracts*. 2Ed. Boston: Mc-Graw-Hill.

Huang, X and Hinze, J (2006) Owner's Role in Construction Safety: Guidance Model. *Journal of Construction Engineering and Management,* **132**(2), 174–81.

Levitt, R E and Samelson, N M (1987) Putting accident costs up front. *In: Construction safety management.* New York: Mc-Graw-Hill, New York.

Ministry of Manpower (2005) *Guidelines on risk assessment.* Singapore: MOM. Available online: http://www.mom.gov.sg/NR/rdonlyres/C6119ECB-3F11-4848-8071-C0A44627720B/5552/RiskAssessmentGuidelinesV65.pdf (accessed 28 September 2005).

Peckitt, S and Coppin, S (2005) Revitalising Environmental, Health and Safety & Management in Public Sector Construction Projects – Case Study of the Department for Work & Pensions Jobcentre Plus Rollout Project. *In: CIB W99 (4th Triennial International Conference), Rethinking and Revitalizing Construction Safety, Health, Environment and Quality,* 17–20 April, Port Elizabeth, South Africa.

Sikes, R W, Qu, T. and Coble, R J (2000) An owner looks at safety. In: R Coble, J Hinze and T Haupt (Eds.) *Construction safety and health management*. Upper Saddle River, NJ: Prentice-Hall.

Suraji, A, Duff, A R and Peckitt, S J (2001) Development of casual model of construction accident causation. *Journal of Construction Engineering and Management*, **127**(4), 337–44.

Teo, A L E, and Ling, Y Y F (2006) Developing a model to measure the level of Construction site safety. *Building and Environment*, **41**(11), 1584–92.

Teo, A L E, Ling, Y Y F and Chua, K H D (2004) *Measuring the effectiveness of safety management systems of construction firms*. Singapore: NUS.

Ward, S C, Chapman, C B and Curtis, B (1991) On the allocation of risk in construction projects. *International Journal of Project Management*, **9**, 140–7.

Workplace Safety and Health Act (WSHA 2006) Singapore: MOM. Available online: http://www.mom.gov.sg (accessed 9 February 2006).

PROJECT MANAGER PERFORMANCE

Motiar Rahman,[1] Christopher Miller,[2] Gary Packham,[2] Nabil Sawakhroon[3] and Ji Meng[1]

[1]*Faculty of Advanced Technology, University of Glamorgan, Pontypridd, CF37 1DL, UK*
[2]*Welsh Enterprise Institute: University of Glamorgan Business School, Pontypridd, CF37 1DL, UK*
[3]*Ministry of Defence Engineering Services, Project Directorate, Muscat – Seeb, Post Code 111, Oman*

An array of skills and attributes are necessary in order to responsibly carry out the duties of project managers (PMs), in delivering successful projects. The purpose of this paper is to identify and assess various necessary skills and attributes of PMs for project success. Results from statistical analyses of 155 questionnaire responses from China, Oman and the UK are presented. Despite the evident differences of perceptions among respondents on the relative priorities of various items, it was observed that a balanced set of various skills is essential for PMs, with leadership abilities for teamworking and meeting the project objectives. Although the skills related to "education" appear to be less important than some other skills, results indicate that there is no alternative of formal training and education. Respondents also consider that an attitude for attaining a satisfactory level of customer satisfaction and approach to teamworking are among the two most important attributes of PMs that lead to project success, along with the ability to complete the project on time, within budget and to an acceptable quality. The overall results indicate the readiness of the respondents in these three countries to consider some 'non-traditional' skills and attributes that PMs should possess to deliver successful projects.

Keywords: China, leadership, Oman, project manager, skills, United Kingdom.

INTRODUCTION

The success of construction projects depends on a multitude of factors, including human-related factors, project-related factors, project procedures, project management actions and the external environment (Chan *et al*. 2004). Arguably, project managers (PMs) play the central role, directly or indirectly, in addressing such diverse – both seen and unforeseen – issues for delivering a successful project. The PM, as either a company or an individual (Wang and Huang 2006), is responsible for managing a project to deliver it in the agreed schedule, to the correct technical specification (defined to meet user requirements) and within the approved budget and other specified criteria, i.e. key performance indicators (BoK 2000). The PM is also responsible for leading the whole project team, including establishing a direction, aligning people, and motivating and inspiring (PMBOK 2004). Therefore, the PM should not only be able to successfully carry out the works in terms of technical ability, such as those relating to time, quality and cost, but also be able to effectively mobilize coordinating, motivating and collaborating efforts in terms of relational harmony, such as approach to teamworking. Understandably, the PMs need to have an array of skills and attributes in order to carry out their responsibilities soundly, as well as to deliver projects successfully.

[1] mrahman@glam.ac.uk

There is a trend of inter-changeably using the terms PM, project management and leadership (Turner 2006). This is perhaps due to the (1) emergence of various collaborative working arrangements (CWAs) in construction based on teamworking concept, where the management of relationships and other soft issues among different contracting parties are considered critical and (2) consequent changes in the role of PMs in delivering their project management activities. Kolltveit *et al*. (2007) reveal that today the leadership perspective of project management is the dominant one, while earlier the task perspective was the most emphasized. Other researchers advocate that leadership is critical for the performance of the project team (Weinkauf and Hoegl 2002; Callanan 2004; Natal *et al*. 2004; Wing 2005). A leader must acknowledge, embrace and manage (or deliver) aspects to yield positive results from teamwork (PMI 2006). An adjusted set of skills for PM appears to be necessary to address such a changed environment. Hence, the importance of this exploratory study for identifying and prioritizing various skills and attributes of PM, with an appreciation of the changes in the role of PMs, and before suggesting a general guideline for PMs to meet the challenges in their changed/new roles.

Relevant previous studies include: (1) identification of different factors hindering the performance of construction PMs (Powl and Skitmore 2005); and (2) investigations into the relationships between roles, skills and professions of project managers (Wilkinson and Palmer 2006). None of these studies considered the changed roles of PMs in CWAs. The present study delves somewhat deeper into specific aspects, in that it is attempting to address the changed roles of PMs in CWAs and assessing various skills and attributes of PM, for their prioritization. The overall research project has been approached through the multiple methods of literature review (stage one), questionnaire survey (stage two), and interviewing industry experts (stage three). In stage two of this study, the questionnaire survey was carefully designed to meet the objectives of prioritizing (1) various necessary skills or qualifications, and (2) attributes or approaches of PM, that contribute to project success or failure, especially with an appreciation of present trend of CWAs in construction. This paper presents the interim outcomes of the study and reports the perceptions of 155 respondents (see Table 1) from China, Oman and the UK. Space limitations only permit the presentation of key extracts of the results.

QUESTIONNAIRE SURVEY

The questionnaire was developed in the UK, on the basis of a wider literature review, and to meet the above objectives. Individual items of the questionnaire were sourced from 11 better practices for improvement of leadership as suggested by Behn (2004); 15 factors hindering the performance of construction PMs as reported by Powl and Skitmore (2005); various roles, skills and professions investigated through 14 questions by Wilkinson and Palmer (2006); and 111 potential facilitating and deterring factors for various CWAs reported by Rahman *et al*. (2007). The individual factors were selected and tuned to suit the specific purposes of the present study, namely their prioritization, including allowing evaluation of generic or traditional skills and attributes in the changed environment, and assessing the importance of other factors to address the changed environment. The questionnaire was then (1) pilot tested by two practitioners from Oman, two practitioners from the UK and one academic from the UK with extensive knowledge in Chinese construction industry, and (2) improved based on the opinions received from these experts. The questionnaire included two specific sections requesting the respondents to express their perceived importance on a scale from 1–10 (varying from lowest to highest) on: 32 skills or qualifications and 28 attributes or approaches of PM, which contribute to project success or failure in general (see Appendix). Two MSc students were engaged to carry out the survey: one in China and the other one in Oman and the UK. Literature suggests that the practice of modern project management and CWAs in China are relatively new (Wang and Huang 2006). The practice of the former is not new in Oman, but traditional procurement systems are still dominant (Sawakhroon 2006). On the other hand, the both are well practised and documented in the UK. It was therefore expected that the questionnaire survey in these three different countries would yield an interesting comparison. In particular, this will help collect more 'problems' and their potential solutions, allowing the proposed general guidelines useful.

As shown in Table 1, 155 responses were received, with an average total experience of 11.4 years. At the time of the survey, 53 respondents were holding the senior level position, whereas other 69 and 33 respondents were holding mid-level and junior level positions respectively, showing a balance between the number of respondents, to some extent. However, the number of respondents from China (85) was more than the total of those from Oman (33) and the UK (37). Also, respondents from China have relatively less total experience (7.5 years) compared to those from Oman (18.8 years) and the UK (13.9 years).

Table 1: Questionnaire distribution and respondent profile

Items		**China**	**Oman**	**UK**	**Total**
Questionnaire distributed:		300	80	160	540
Responses received:	Contractor	14	24	33	71
	Consultant	9	7		16
	Academic	10		4	14
	Private Client	36	2		38
	Public Client	16			16
	Total	85	33	37	155
Response rate in percentage:		28.3	41.3	23.2	28.7
Whether worked as PM:	Yes	38	24	26	78
	No	47	9	21	77
Nature of Job:	Engineering	25	22	18	65
	Managerial	48	11	16	75
	Academic	12		3	15
Level of Job:	Senior	16	24	13	53
	Mid-level	47	9	13	69
	Junior	22		11	33
Total experience:	Average in years	7.5	18.8	13.9	11.4
	Range (years)	2–35	5–42	1–45	1–45
Experience at present level:	Average in years	5.05	10.39	5.69	6.34
	Range (years)	1–20	1–25	1–23	1–25

For the purposes of this paper, the mean scores of different groups of respondents (based on country and also the whole sample as total) on individual factors were ranked and compared. Statistical t-tests of the mean at significance level 0.05 were undertaken to establish whether each factor is significantly important. ANOVA was carried out at 95% confidence level to determine whether the three groups of respondents had different perceptions on the relative importance of various factors. Factor Analysis was carried out to narrow down the long list of factors into a smaller number of representative components. For the purpose of this exercise, the Principal

Component method of extraction was applied, coupled with Varimax with Kaiser Normalization method of rotation. Eigenvalues for the extracted components of ≥ 1.0 were considered, and "factor loadings" of ≥ 0.40 were considered to contribute to different components. However, for the purposes of brevity, t-test results of only the total sample are shown in Table 2. In addition, only the key extracts of the results are summarized here, in order to meet the space limitations.

RESULTS

Comparison of means: necessary skills/qualifications of PM

Table 2 shows the perceptions of respondents on 32 factors that express various skills/qualifications necessary for PM to carry out different duties and responsibilities, along with significance obtained from one sample t-test for the total sample, and the ANOVA results for the groups of three countries.

Table 2: Comparison of means and ANOVA results of various skills/qualifications of PM

Factor*	China		Oman		UK		Total			ANOVA
	Mean	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Mean**	**Rank**	**Sig.**	
f02	8.19	1	7.73	3	8.11	3	8.07	1	.000	.396
f18	8.07	3	7.53	6	7.86	7	7.91	2	.000	.317
f24	7.94	4	7.61	4	8.05	4e	7.90	3	.000	.463
f01	7.93	5	7.85	1	7.76	13	7.87	4	.000	.858
f22	8.08	2	6.91	28e	7.81	8	7.77	5	.000	.003
f05	7.44	10	7.79	2	8.43	1e	7.75	6	.000	.015
f11	7.75	7	7.39	10	7.78	9e	7.68	7e	.000	.519
f19	7.80	6	7.24	14	7.78	9e	7.68	7e	.000	.283
f14	7.52	9	7.52	7e	7.68	14e	7.56	9	.000	.893
f13	7.66	8	7.00	21e	7.68	14e	7.52	10	.000	.152
f12	7.27	14	7.27	12e	7.95	6	7.43	11	.000	.071
f20	7.36	13	7.12	16	7.78	9e	7.41	12	.000	.325
f04	7.42	11	7.00	21e	7.65	16	7.39	13	.000	.294
f32	7.05	20	7.30	11	7.78	9e	7.28	14e	.000	.101
f15	7.15	17	7.42	9	7.43	20	7.28	14e	.000	.655
f03	6.98	22	7.55	5	7.51	18	7.22	16	.000	.198
f10	6.56	29	7.52	7e	8.43	1e	7.21	17	.000	.000
f06	6.85	24	7.09	17e	8.05	4e	7.19	18e	.000	.002
f17	7.39	12	6.91	28e	6.97	24e	7.19	18e	.000	.306
f29	7.21	15	7.27	12e	6.84	27	7.14	20	.000	.539
f30	7.20	16	6.97	24e	7.00	22e	7.10	21	.000	.769
f09	7.14	18	7.03	19e	7.00	22e	7.08	22	.000	.922
f16	7.09	19	7.09	17e	6.97	24e	7.06	23	.000	.925
f23	6.82	25	6.94	27	7.49	19	7.01	24	.000	.140
f21	6.77	26	6.58	32	7.57	17	6.92	25e	.000	.034
f31	6.74	27	6.97	24e	7.27	21	6.92	25e	.000	.262
f26	6.73	28	6.61	31	6.92	26	6.75	27	.000	.709
f07	6.87	23	7.22	15	5.71	31	6.68	28	.000	.005
f25	6.99	21	6.73	30	5.86	29	6.67	29	.000	.004
f28	6.19	31	7.03	19e	6.14	28	6.36	30	.000	.051
f27	6.29	30	6.97	24e	5.82	30	6.34	31	.000	.064
f08	6.13	32	7.00	21e	5.49	32	6.16	32	.000	.019

Notes: *Please see Appendix for detail description of the factors.
Rank: 'e' signifies equal rank and the next rank(s) is/are omitted, except the lowest rank where the previous rank(s) is/are omitted.

It is seen that “ability to effectively direct, manage and motivate the project team” (f02, score 8.07) is the most important skill of PM. This perhaps point to the fact that PMs must have a balanced set of various skills, instead of being ‘champion’ in any specific skill. However, this is followed by “leadership” (rank 2, score 7.91), “ability to meet project targets and objectives” (rank 3, score 7.90), “ability to effectively apply standard project management tools/ approaches” (rank 4, score 7.87) and “preparing and maintaining the project execution plan” (rank 5, score 7.77). “Build and maintain effective means of communications” is the 6th most important skill, whereas “experience” (f11) and “managing the project for the required deliverables” (f19) share the equal rank of 7. It is observed that factors ranking from 2 to 7 do not show any specific trend. Although very important, they simply show the level of their individual importance when compared with other factors. However, the top-ranked factor appears to have fed from all these skills, since these skills are essential “to effectively direct, manage and motivate the project team”.

The relative importance of some other factors are, in terms of ability of PM, on “proactive decision making” (f14, rank 9), “clear communications” (f13, rank 10), “defining and clarifying project objectives” (f20, rank 12), “tailoring expert knowledge” (f04, rank 13), “developing and implementing detailed stage/ milestone plan” (f03, rank 16), “quality management” (f06, rank 18e), and “proactive risk management” f26, rank 27). Relatively less importance on skills related to managing “quality” and “risk management” may taken to be interpreted as such skills are supposedly covered in “proactive decision making”, “clear communications” and “tailoring expert knowledge”.

“Knowledge” (f12, f32) of a PM is more important (ranks 11 and 14) than “personal attitude and motivation” (f10, rank 17), “professional ethics” (f29, rank 20), “technical competency” (f30, rank 21) and “legal awareness” (f16, rank 23). On the other hand, “financial awareness” (f17, rank 18) is more important than “influencing budget” (f31, rank 25e), whereas contextual “training” (f09, rank 22) is more important than any formal “education” (ranks 28–32). “Level of education: masters and above” (f08) is seen to be the least important factor with the score of 6.16, which is more than the average (i.e. 5.50) of the measuring scale (i.e. 1–10), implying a general importance of all the 32 factors. This is confirmed by the one-sample t test: all the factors expressing various skills/ qualifications of PM are significant, both in the total sample and in the groups of three countries, except the five education related factors in the UK group (f07, f08, f25, f27 and f28). General importance of all the factors may be taken to imply the respondents’ readiness of practising all the skills of PM identified in this study, including those are non-traditional. Although ranks of individual factors within different groups are different, ANOVA results show that respondents from three countries have similar perceptions on 24 factors. However, they significantly disagree on the relative importance of eight factors (f05, f06, f07, f08, f10, f21, f22, f25). There might be a number of reasons for such disagreements.

For example, the ranks of the factor relating to “effective means of communications” (f05) in the groups of the UK (rank 1e) and Oman (rank 2) are close, but their scores are considerably different (UK 8.43, Oman 7.79). On the other hand, the score of this factor in the group of China is sufficiently close (7.44) to that of Oman, but with a rank of 10. This led to the rank of 6 in the total sample with a score of 7.75. This might be due to the reason that respondents from China have less total experience in construction, than those from the UK and Oman. Moreover, the practice of project management in China is relatively new (Wang and Huang 2006), so is the use of teamworking-based approach in construction (Ji 2006). Therefore, they are yet to appreciate the appropriate importance of "effective communications" (f05). On the other hand, respondents from Oman have considerably high total experience (18.8 years, see Table 1), as well as rich in international construction experience (Sawakhroon 2006). Respondents from the UK have sufficiently high total experience (13.9 years), with a culture of teamworking-based approach in construction. Such background of the respondents from Oman and the UK might have led to highly appreciate the importance of "effective communications", which is different with those from China.

Comparison of means: factors/attributes related to PM for project success

It was seen that completing the project on time (ff01), with satisfactory customer satisfaction (ff04) and within budget (ff02) are the top-most three factors related to PM for project success. PM's approach to teamworking (ff13, rank 4) and motivate the project team (ff17, rank 7) is very important. So is to ensure acceptable quality (ff03, rank 5) and approach to quality management (ff05, rank 6). Respondents consider that PM's ability to influence top management (ff18, rank 8) is more important than relationship with top management (ff24, rank 14), building relationship within the project team (ff19, rank 21), as well as relationships with other parties (ff25, rank 23). Approach to coordination (ff21, rank 10) is more important than leading the whole project team (ff23, rank 13), risk management (ff10, rank 15), open communication (ff16, rank 17e), conflict management (ff12, rank 25e) and change management (ff22, rank 25e).

Moreover, professional ethics (ff14, rank 11) is more important than innovative ideas (ff16, rank 16), service of the same PM during the entire project period (ff15, rank 19e), mentoring junior officials (ff27, rank 22) and delegate authority (ff08, rank 24). Respondents do not appear to enthusiastically recommend non-contractual relationships (ff20, rank 27), and 'fit for purpose' (instead of written specifications) (ff28, rank 28) is seen to be the least important factor, showing the preference of the respondents on the written contracts, instead of unwritten commitment or transactions. However, the score of this least important factor is 6.91, which is higher than the average of the measuring scale (i.e. 5.50). This implies a general importance of all the factors, with some factors more important than some others. This is confirmed by the one-sample t test. The significance levels obtained from the t-test of all the factors are less than 0.05, both in the total sample and in the groups of three countries, indicating that all the factors/attributes related to PM for project success are significantly important. However, general importance of all the factors may imply readiness of respondents' from the three countries of practicing all the skills of PM identified in this study, including the non-traditional ones. It may also be taken to apply a gradual or step-wise focus of implementing different factors or attributes, according to their priority of relative importance.

On the other hand, the ranks of individual factors in the three groups of respondents are mostly different. ANOVA results show that respondents from three countries significantly agree on the relative importance of 14 factors only, and disagree on other 14 factors. This may be due to the diverse origin, practice and overall experience in construction of the respondents. Space restrictions do not permit a detail discussion, which is expected to be presented in a follow-up paper, if suitable.

Factor analysis: necessary skills/qualifications of PM

Table 3 shows the summary of the outcomes from "factor analysis" for necessary skills/ qualification of PM. Explaining over 62% of the total variations, seven components were extracted from this exercise: (1) ensuring project execution and meeting the objectives; (2) proactive decision making appreciating underlying environment; (3) adequate knowledge and experience for leadership; (4) effective use of standard project management tools; (5) appropriate education and training; (6) professional development and proactive risk management; and (7) technical competency and ability to influence budget. Ten factors are seen to contribute to more than one component, with some factors contributing equally or almost equally to two components. For example, factor f32 contributes to components 1 and 2 with equal factor loadings of 0.47, whereas factor f10 contributes to components 4 and 2 with factor loadings of 0.45 and 0.44 respectively. Such 'primary' and 'secondary' contributions loosely inter-relate all the components, either directly or indirectly, suggesting the requirement for a balanced set of skills for PM, except component 5. None of the factors of component 5 contribute to any other components, suggesting unique importance of 'education and training'.

Table 3: Factor analysis outcomes of necessary skills/qualifications of PM

Components	Primary factors*	Secondary factors*	Eigen-values	% of Var. explained (cumulative)
1: Ensuring project execution and meeting the objectives	f18, f19, f20, f22, f23, f24, f32	f17, f21	3.97	12.4 (12.4)
2: Proactive decision making appreciating underlying environment	f14, f15, f16, f17, f21	f10, f13, f20, f32	3.39	10.6 (23.0)
3: Adequate knowledge and experience for leadership	f02, f11, f12, f13	f05, f14, f24	3.17	9.91 (32.91)
4: Effective use of standard project management tools	f01, f03, f04, f05, f06, f10		3.07	9.6 (42. 51)
5: Appropriate education and training	f07, f08, f09, f25		2.44	7.62 (50.13)
6: Professional development and proactive risk management	f26, f27, f28, f29		2.33	7.27 (57.4)
7: Technical competency and ability to influence budget	f30, f31	f28	1.78	5.57 (62.97)

Notes: Rotation converged in 15 iterations. Kaiser-Meyer-Olkin Measure of Sampling Adequacy was 0.835. Bartlett's Test of Sphericity: Approx. Chi-Square 2225, df 496, $p<0.000$. *See Appendix

Factor analysis: factors/attributes related to PM for project success

Six components emerged, and together they account for over 63% of the total explained variations. Those are: (1) structured collaboration and relationship management; (2) leadership, teamworking and issue resolution; (3) effective project control – budget, time and quality; (4) management of project risks, utilities and deliverables; (5) continuity of service and mentoring; and (6) customer satisfaction. All the components are seen to feed from the factors that contribute to more than one component, and, as such, eight factors are seen to contribute to two components. Several factors are seen to contribute almost equally to two components, e.g. the factor 'approach to fit for purpose' (ff28) is seen to contribute to components 1 and 5 with factor loadings of 0.54 and 0.58 respectively. Thus, all the components are interrelated with 'primary' and 'secondary' contributions, either directly or indirectly, although nomenclature of different components (as above) is based on their 'primary' contributing factors only.

FUTURE WORK

The paper presents the interim outcomes from the preliminary observation of the research process. The next stage of this research agenda is to conduct an interview-based survey. This is planned to collect expert opinion in an attempt to explore the various (1) reasons of the commonalities and disagreements between the three countries as seen above, and (2) potential means of generalizing the diverse opinion, including the necessity of any tailor-made activities, in order to devise a general guideline for PMs. It is expected that the latter investigations will allow far more detailed comparisons of country specific differences of opinions and their commonalities as well.

CONCLUSIONS

Project Managers (PMs) need to deal with a range of issues for successful delivery of construction projects. PMs therefore need to equip themselves with an appropriate set of various skills and/ or attributes, not only to successfully carry out their works in terms of technical ability, such as those relating to time, quality and cost; but also to effectively mobilize coordinating, motivating and collaborating efforts in terms of relational harmony, such as approach to teamworking. However, some of the skills and/or attributes may be more useful than some others. This is important, especially due to the changing roles of PMs affecting from the emergence of various collaborative working arrangements in construction. As such, various skills and attributes were identified in this exploratory study, in order to ascertain their relative importance and to offer any incentive in designing appropriate strategies for PMs in delivering their duties soundly. Results led to the following observations:

- All the 32 necessary skills/qualifications identified in the study were found to be significant. In addition, respondents from three countries significantly agreed on the relative importance of most of the listed skills/qualifications.
- All the 28 factors/attributes related to PM for project success were found to be significant. However, the three groups of respondents significantly agreed on the relative importance of 14 factors and disagreed on the other 14 factors.
- It was found that a balanced set of various skills and attributes is essential for PMs, with leadership abilities for teamworking and meeting the project objectives in terms of time, cost and quality.
- The priority of a few non-traditional approaches was also noticed, including ensuring customer satisfaction.
- The general importance of all the items relating to various skills and attributes of PM for project success was interpreted to imply a gradual or step-wise implementation, according to their relative importance, and to reflect the readiness of the respondents to practice some non-traditional approach, e.g. customer satisfaction.
- The factor analysis exercise extracted seven and six components for (1) necessary skills/qualifications of PM and (2) various factors/attributes of PM for project success, respectively.
- On the whole, results from factor analysis suggest the need for consolidated but interrelated approaches, both for various necessary skills, factors/attributes of PM for project success, with unique importance of formal training and institutional education.

The paper presents the preliminary observations only. Further investigations are expected to allow more detailed comparisons among different countries.

REFERENCES

Behn, R D (2004) *Performance Leadership: 11 Better Practices That Can Ratchet Up Performance*. Washington, DC: IBM Center for The Business of Government.

BoK (2000) Body of Knowledge (BoK), Association for Project Management (APM), UK.

Callanan, G A (2004) What would Machiavelli think? An overview of the leadership challenges in team-based structure. *Team Performance Management*, **10**(3/4), 77–83.

Chan, A P C, Chan, D W M, Chiang, Y H, Tang, B S, Chan, E H W and Ho, K S K (2004) Exploring critical success factors for partnering in construction projects. *Journal of Construction Engineering and Management*, **130**(2), 188–98.

Kolltveit, B J, Karlsen, J K and Grønhaug, K (2007) Perspectives on project management. *International Journal of Project Management*, **25**, 3–9.

Meng, J (2006) *Performance of client's project manager in China*, Unpublished MSc thesis, University of Glamorgan, UK.

Natale, S M, Sora, S A and Kavalipurapu, S B (2004) Leadership in teams: managerial responses. *Team Performance Management*, **10**(3/4), 45–52.

Pheng, L S and Chuan, Q T (2006) Environmental factors and work performance of project managers in the construction industry. *International Journal of Project Management*, **24**, 24–37.

PMBOK (2004) *Project Management Book of Knowledge (PMBOK)*. USA: Project Management Institute (PMI).

PMI (2006) *Leadership*. USA: Project Management Institute (PMI).

Powl, A and Skitmore, M (2005) Factors hindering the performance of Construction Project Managers. *Construction Innovation*, **5**, 41–51.

Rahman M M, Kumaraswamy, M M and Ling, F Y Y (2007) Building a relational contracting culture and integrated teams. *Canadian Journal of Civil Engineering*, **34**(1), 75–88.

Sawakhroon, N (2006) *The Project Manager Performance: Working for Contractor*, unpublished MSc thesis, University of Glamorgan, UK.

Turner, J R (2006) Editorial: Towards a theory of project management: The nature of the functions of project management. *International Journal of Project Management*, **24**, 277–9.

Wang, X J and Huang, J (2006) The relationships between key stakeholders' project performance and project success: Perceptions of Chinese construction supervising engineers. *International Journal of Project Management*, **24**, 253–60.

Weinkauf, K and Hoegl, M (2002) Team leadership activities in different project phases. *Team Performance Management*, **8**(7/8), 171–82.

Wilkinson, S J and Palmer, A (2006) Skills and qualities and the effective project manager in the UK construction industry. *In:* A N Baldwin, E C M Hui and F K W Wong (Eds.) *The Proceedings of BEAR2006: Construction Sustainability and Innovation*, 10–13 April 2006, The Hong Kong Polytechnic University, Hong Kong.

Wing, L S (2005) Leadership in high-performance teams: a model for superior team performance. *Team Performance Management*, **11**(1/2), 4–11.

APPENDIX

Necessary skills/qualifications of project manager (PM) in general

(f01) Ability to effectively apply standard project management tools/approaches to the specific requirements of the project. (f02) Ability to effectively direct, manage and motivate the project team. (f03) Ability to effectively develop and implement detailed stage/milestone plan. (f04) Ability to effectively tailor expert knowledge to meet specific circumstances. (f05) Build and maintain effective means of communications with other parties involved in the project as required. (f06) Ability to apply quality management principles and processes. (f07) Level of education: undergraduate. (f08) Level of education: Masters and above. (f09) Level of training received.(f10) Personal attitude and motivation. (f11) Experience gathered. (f12) Knowledge acquired. (f13) Ability to communicate clearly. (f14) Ability to make decisions proactively. (f15) Negotiation skills. (f16) Legal awareness. (f17) Financial awareness. (f18) Leadership. (f19) Managing the project for the required deliverables. (f20) Ability to define and clarify project objectives. (f21) Management of resources, including their procurement and/ or mobilization. (f22) Preparing and maintaining the project execution plan. (f23) Ability in identifying and obtaining any support and advice required for managing, planning and controlling the project. (f24) Ability to meet project targets and objectives. (f25) Educational background in project management. (f26) Ability in managing dynamic/proactive risk management strategies. (f27) Educational background in civil engineering. (f28) Educational background in other disciplines (e.g. building services, quantity surveying, etc.). (f29) Professional ethics. (f30) Technical competency. (f31) Ability to influence budget. (f32) Good overall knowledge.

Factors/attributes related to PM for project success in general

(ff01) To complete the project on time. (ff02) To complete the project within budget. (ff03) To ensure acceptable quality. (ff04) To attain satisfactory level of customer satisfaction. (ff05) Approach to quality management. (ff06) Designing and applying an appropriate execution plan for the project. (ff07) Production of the required deliverables of the project. (ff08) Approach to delegate authority. (ff09) Planning and monitoring of all utilities of the project. (ff10) Approach to risk management and/ or sharing, including any contingency plans. (ff11) Ensure project progress and usage of resources, including any corrective action where necessary. (ff12) Approach to conflict management and/ or issue resolution. (ff13) Approach to team working. (ff14) Professional ethics. (ff15) Service of the same PM during the entire project period. (ff16) Approach to open communication within the project team, up to a certain level. (ff17) Ability to motivate project team. (ff18) Ability to influence top management. (ff19) Approach to building relationship within the project team. (ff20) Approach to non-contractual relationships. (ff21) Approach to coordination. (ff22) Approach to change management. (ff23) Approach/ attitude in leading the whole project team. (ff24) Relationship with top management. (ff25) Relationships with other parties. ff26) Approach to innovative ideas. (ff27) Approach to mentoring junior officials, e.g. through on-the-job training. (ff28) Approach to 'fit for purpose', instead of written specifications.

PERFORMANCE IMPROVEMENT THROUGH PLANNING OF CONSTRUCTION OPERATIONS

John C. Hildreth,[1] Michael C. Vorster[1] and Hank Adams[2]

[1]*Charles E. Via, Jr. Dept. of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University, 200 Patton Hall, Blacksburg, VA 24061-0105, USA*
[2]*Kiewit Constructors, Inc., 470 Chestnut Ridge Road, 2nd Fl. Woodcliff, NJ 07677, USA*

Construction operations can be categorized as either routine and repetitive or unique and complex. Routine and repetitive construction operations can be improved through traditional field operations analysis techniques, while unique and complex operations can be improved through reactively analysing and proactively planning similar operations. The intent of planning is to assemble the information and knowledge necessary to successfully execute the work. Plans are developed under the general headings of safety, quality, and operational performance. A laboratory exercise was developed to demonstrate the effectiveness of reactively analysing and proactively planning operations. Construction duration was reduced by approximately 40% and significant improvements were reported in material handling, understanding of responsibilities and work flow efficiency.

Keywords: construction planning, construction process, education, planning, site operations.

INTRODUCTION

Construction operations can be classified as either “routine and repetitive” or “unique and complex.” The methods and techniques used to understand and improve operational performance are different for each classification. Traditional techniques of field operations analysis are applied to improve routine and repetitive operations. Unique and complex operations do not present the opportunity to analyse previous performance. Such operations can be improved through a reactive analysis of a similar operation to develop an understanding and then drawing upon this knowledge to proactively plan the upcoming operation.

The traditional methods for improving routine and repetitive operations are well documented in the literature. To gain an understanding of planning for unique and complex operations, the proactive planning methods of a successful heavy civil contractor have been studied and are presented under the general headings of safety, quality, and operations planning.

Methods for operations analysis and improvement are an integral portion of a construction engineering and management education program. The Construction Performance Improvements courses at Virginia Tech have been restructured to include a specific laboratory exercise aimed at demonstrating the benefits of detailed operations pre-planning for unique and complex construction operations.

[1] hildreth@vt.edu

OPERATIONS IMPROVEMENT TECHNIQUES

Techniques for improving construction operations are applied either during or prior to construction. Field operations analysis techniques are applied to ongoing operations to record data, analyse performance, identify problems and devise solutions (Oglesby *et al*. 1989). Prior to operational performance, a proactive planning process may be employed to gather information, develop an operations pre-plan and disseminate the information to the involved parties.

Repetitive operations analysis

Routine and repetitive construction operations are those comprised of cycles that can be optimized through traditional productivity analysis and improvement techniques. The techniques applied have developed over time, but are fundamentally based on time studies performed to record the time required to complete various tasks comprising repetitive construction cycles (Oglesby *et al*. 1989).

Field operations analysis was originally performed by observers using stopwatches and manually recording data. Oglesby *et al*. (1989) noted several limitations to the technique including difficulties in determining exact start/stop points in a cycle, difficulties in observing multiple cycle components, and data being subject to the physical limitations and biases of the observer.

Time-lapse photography improved field operations analysis by providing all the information that makes such studies beneficial. Oglesby *et al*. (1989) noted that time-lapse photography is able to record the interrelationships between observed resources and provides an easy to understand permanent record. Sprinkle (1972) investigated its use and found a single camera is able to replace multiple observers and the resulting data can be repeatedly reviewed without doubt regarding is accuracy.

Video recordings replaced time-lapse photography due to the advantage of instant replay, continuous recordings, and less expensive and more reliable equipment (Oglesby *et al*. 1989). Video recording has been used to document the construction of entire projects (Everett et al. 1998) and in field operations analysis (Bjornsson and Sagert 1994). While an improvement over photographic methods, the primary disadvantage of real-time recordings is the time required to review the data. Digital video has helped to overcome this shortfall and with the aid of software can be viewed at speeds up to 32 times real time. In practice, it has been found that speeds greater than four times real time result in discontinuous or “jumpy” videos.

Observational techniques that rely on visual data are subject to two principle limitations: data is limited to that within the field of view of the observer or camera and the analyst must make instantaneous decisions regarding the start/stop of tasks based on visual information. On-board instrumentation systems have been employed to overcome these limitations (Hildreth *et al*. 2005; Kannan and Vorster 2000). Sensor data is recorded and analysed through automated techniques to identify the timing of key points in a production cycle.

While each of the analysis techniques presented has been successfully employed, each is predicated on the availability of repetitive cyclical field operations for observation and analysis. Ongoing operations are analysed and improvements identified are implemented on the studied operation and subsequent operations.

Unique operations analysis
Unique and complex operations are, by definition, operations that have not been performed previously and do not present an opportunity for analysis and improvement through traditional techniques. The operation life cycle shown in Figure 1 can be applied to understand performance and identify potential improvements.

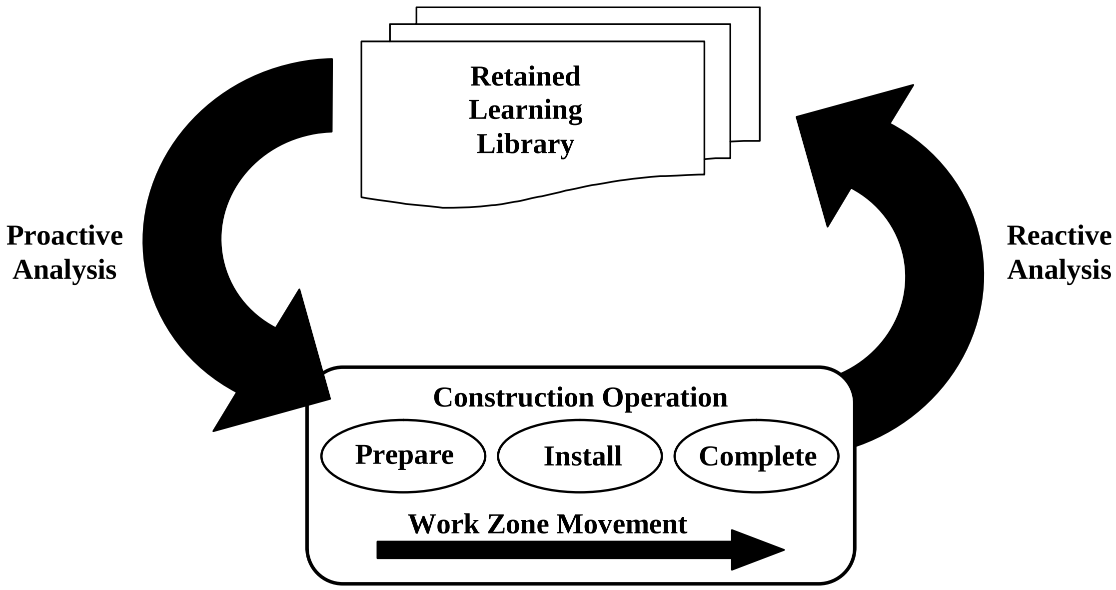


Figure 1: Operation life cycle (Casten 2007)

Reactive analysis of a completed operation is an opportunity to analyse performance and learn how to plan and improve similar operations. Analysis begins with the steps required to perform the operation. Steps are categorized as either value adding or non-value adding, where value adding steps are those that directly contribute to the completion of the work (Casten 2007). Non-value adding steps may be those that contribute to performance, but not completion, or those steps that are unnecessary. Analysis of value adding steps is an opportunity to understand and improve the workflow, while analysis of non-value adding steps is an opportunity to improve operational support and eliminate waste. An analysis of wastes identified in the performance allows delay-free construction time to be estimated and waste free performance to be envisioned. Opportunities for improvement can be identified through a reactive analysis such that behaviours and habits can be better understood and accommodated.

The lessons learned through reactive analysis should be documented and archived in a retained learning library that can be used when proactively planning similar operations (Casten 2007). Proactive planning involves analysing an operation, planning its performance, preparing for performance, and disseminating the information. Analysis includes defining and quantifying specific tasks required for completing the overall scope of the operation. Materials from the retained learning library may be used in developing an initial workflow scheme. Operational planning is the assignment of responsibility, means and methods, physical space, and time of performance to each task. Preparing to perform an operation may include developing work zone drawings, physical or computer models, procuring the necessary inputs, completing prerequisite work, or making special site preparations. The final stage of a proactive analysis is to disseminate the information to the work crew. This can be achieved through structured meetings to discuss the operation and documentation of the proactive planning process.

EXAMPLE OF PRACTICE

A heavy civil contractor that works globally dedicates a large amount of resources to pre-planning operations and attributes much of the company success to its ability to execute the plans. The intent of pre-planning operations is to assemble in a single document the information and in one person the knowledge required to successfully execute the work in the field. The person is a field engineer that develops the plan under the guidance and assistance of field supervision personnel. Once the plan is approved, the engineer assumes responsibility to direct and supervise execution in the field. The engineer returns to a planning responsibility once the operation is complete.

Formal planning documents principally contain information pertaining to safety, quality, and operations. They are developed and disseminated throughout the organization for discussion and approval. The document is scored for completeness in terms of safety, quality, contingency planning, operations planning, and plans and specifications. Approval comes via the physical signatures of vice-presidents, project managers, safety coordinators, quality coordinators, foremen and each crew member engaged in the operation.

Operations planning
The planning of operations gives consideration to what work is required to perform a specific operation and how it can be best performed. This approach differs from project planning, in which consideration is given to what work the project requires and when activities can be performed.

The operations plan provides general information regarding the work to be performed and specific information pertaining to each step required to complete the operation. The general information includes a description of the work, resource requirements, sequence of work, and budget and target production values in terms of manhours per unit. Sketches, project drawings, catalogue cut sheets, etc. that are applicable are attached. Sketches of the site are used to depict the flow of materials and changes to the site as work progresses.

Safety planning
The safety plan is based on the step-by-step outline of the operation. Principal job hazards are identified along with considerations for the safety of the public in the vicinity of the work. Personal protection equipment requirements are itemized and access/egress points used during the operation are described. Each step in the operation is analysed to identify the associated hazards and preventive actions that are to be taken to avoid the hazard. Care is taken to consider all aspects of the step being performed so that a complete listing of hazards and preventive actions is developed. The personnel responsible for each step is listed and approves the hazard analysis of each step. The plan includes material specifications listing relevant data such as dimensions and weights. Equipment specifications are also included to provide size, type dimensions and lifting capacity. The complete safety plan is reviewed with the crew members and each member signs-off on the plan.

Quality planning

The quality plan is based on the quality requirements identified for each step in the operation. Quality requirements for each step are analysed to identify critical items, actions to get the work built properly, tolerances on each item, and the responsible personnel. There are often multiple critical items for each quality requirement. When possible, checklists are developed to allow for uniform and non-arbitrary quality evaluations in the field. The completed quality plan is reviewed with the crew members and each member signs-off on the plan.

LABORATORY EXERCISE

A portion of the Construction Performance Improvement course at Virginia Tech was designed to provide for learning from the operations life cycle by constructing bridge replicas using K'NEX Real Bridge Building Kits. Students working in groups were tasked with constructing the Tower Bridge with only five minutes to plan their operations. Following construction, a Reactive Analysis and an After Action Review were performed. Plans for the Astoria-Megler Bridge were then provided and students were provided one week to develop a detailed Work Plan. A Before Action Review to discuss, review and communicate the work plan was held after two days and construction was performed one week later. A Reactive Analysis and After Action Review were again performed for the Astoria-Megler Bridge construction.

RESULTS

Results of the exercise indicate that significant improvements can be realized through operations analysis and planning. All groups reported improvements in material handling, understanding of responsibilities and workflow efficiency. While the complexity and number of components were similar for both bridges, the time required for construction was reduced by approximately 40%. The analysis and review reports detail the impressive work performed by the students. The results presented pertain to one group, but the results and examples are representative of the quality of work produced by all groups.

With little time to plan operations, construction of the Tower Bridge required 54 minutes. The Reactive Analysis focused on the non-value added activities and concluded that they accounted for approximately 50% of the time. Non-value added activities were defined as those in which bridge parts were not being assembled. These activities included transporting materials, studying construction drawings, and organizing materials.

The Tower Bridge After Action Review report focused on opportunities for improvement in material handling, communication and coordination, and work group management. It was noted that material organization and handling could be improved through knowledge of the parts required to construct the components assigned to each group member. Communicating responsibilities prior to construction and tracking the completion of components was suggested to avoid duplication of work and allow members to quickly shift focus to their next assigned task. During construction, members focused on the bridge foundations, as these components required completion first. It was noted that improvements in the overall construction process could be realized by focusing members on the components requiring the greatest time to construct. Additionally, it was suggested that the work site be organized to allow connecting components to be constructed in adjacent locations.

Work plan

The Work Plan produced for the Astoria-Megler Bridge focused on assigning responsibility for work components and the tasks required for their assembly to group members. Material lists were compiled for each component to aid material handling and a flow diagram was developed to communicate the work plan.

Eleven bridge components were defined based on the estimated assembly time for each and time at which completion was required. Forty tasks are required to construct the bridge and the tasks for each component were identified. Figure 2 depicts the breakdown of bridge components and assembly tasks.

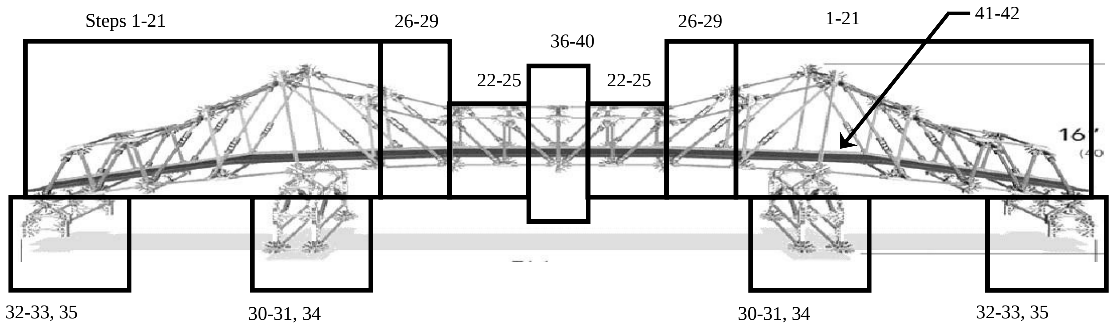


Figure 2: Bridge components and assembly responsibility

The work flow diagram is presented as Figure 3 and indicates the sequence in which assembly of components was planned. Responsibility for components was assigned to individual group members, with all members working towards and responsible for final bridge assembly.

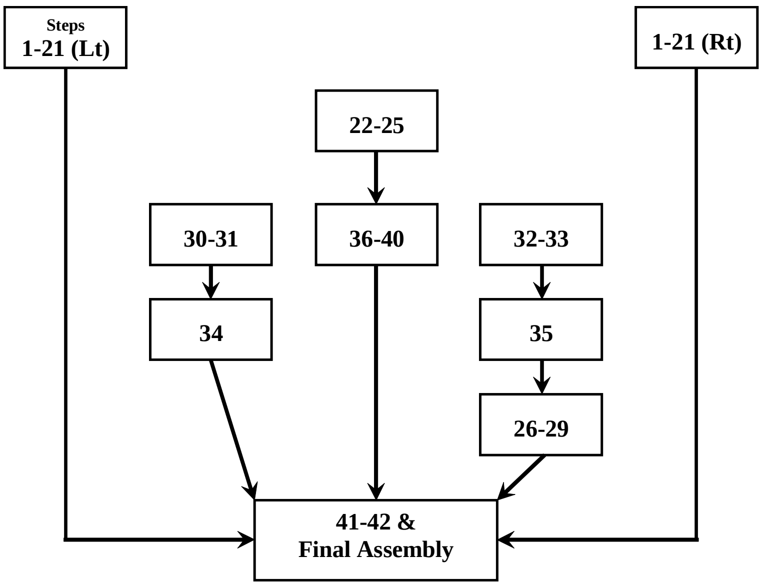


Figure 3: Work flow diagram

Material lists were compiled and provided to each group member. The lists indicate the number and type of materials required for assembly during each task. Materials were organized into separate containers for each component or sub-component. The construction sequence for each group member was included with the material list.

CENTER SPAN & ROAD (Rob)													
Cups	Step	Page	Clips		Connectors		Beams (in order of length)				Roadway		Total
1	22 & 23 A	10			12	2	10	8	6	1			39
2	22 & 23 B	10			12	2	10	8	6	1			39
3	36 & 37 & 38	16			4	2	4		3	1			14
4	24 & 25 A & B	11	8	8					4				20
5	39 & 40	17	8	8					4				20
6	41 & 42	18									5	4	9
Total			16	16	28	6	24	16	23	3	5	4	141

Construction Process:
Rob Sorts Cups 1&2 →Constr Steps 22&23→Sort Cup 3→Constr Steps 36-38→Sort Cups 4&5→Constr 39&40→Road

Figure 4: Typical material breakdown by group member

With planning completed at a great level of detail, a construction schedule was able to be developed to indicate the timing and sequence of 23 work activities. The duration of activities was estimated in minutes. Based on this schedule, the bridge was scheduled to be completed in 24 minutes. The actual time required to construct the Astoria-Megler Bridge was less than 26 minutes, which is less than half of the time required to construct the Tower Bridge.

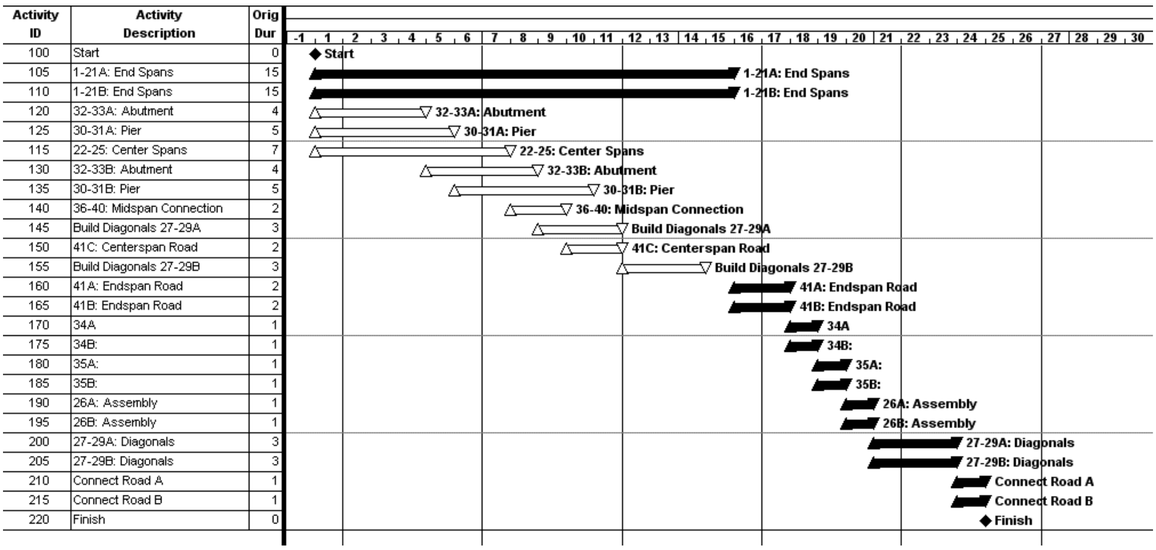


Figure 5: Construction schedule (note: durations in minutes)

CONCLUSIONS

Routine and repetitive construction operations can be improved through traditional field operations analysis techniques, while unique and complex operations can be improved through proactively planning based on reactive analysis of similar operations. Reactive analysis is an opportunity to analyse performance and learn how to plan and improve similar operations. Proactive planning involves analysing an operation, planning its performance, preparing for performance, and disseminating the information.

In practice, the intent of pre-planning operations is to assemble in a single document the information and in one person the knowledge required to successfully execute the work in the field. Success has been achieved engineers planning operations in terms of performance, quality, and safety then managing execution of the plan in the field. Support for the plan is gained by communicating with those directly performing the work.

The effectiveness of this approach for planning and improving unique and complex operations has been demonstrated through a laboratory exercise incorporated into the Construction Performance Improvement course at Virginia Tech. Reactive analysis of one operation led to detailed planning and responsibility assignment for a similar subsequent operation. Construction duration was reduced by approximately 40% and significant improvements were reported in material handling, understanding of responsibilities and work flow efficiency.

REFERENCES

Bjornsson, H C and Sagert, P (1994) Multimedia based system for analysing production organizations. *Computing in Civil Engineering*, **2**, 1405–11.

Casten, M (2007) *Construction Concepts*. Greensboro, North Carolina.

Everett, J G, Halkali, H and Schlaff, T G (1998) Time-lapse video applications for construction project management. *Journal of Construction Engineering and Management*, ASCE, **124**(3), 204–9.

Hildreth, J C, Vorster, M C and Martinez, J C (2005) The Use of Short-Interval GPS Data for Construction Operations Analysis. *Journal of Construction Engineering and Management*, ASCE, **131**(8), 920–7.

Kannan, G and Vorster, M C (2000) Development of an Experience Database for Truck Loading Operations. *Journal of Construction Engineering and Management*, ASCE, **165**(3), 201–9.

Oglesby, C H, Parker, H W and Howell, G A (1989) *Productivity Improvement in Construction*. New York: McGraw Hill Companies.

Sprinkle, H (1972) Analysis of Time-Lapse Construction Films. *Journal of the Construction Division*, ASCE, **98**(CO2), 83–199.

APPLYING AN EXPERIMENTAL APPROACH TO COMPARING CONTRACTORS' BIDDING BEHAVIOUR IN DIFFERENT COMPETITIVE ENVIRONMENTS

Bee-Lan Oo,[1] Derek Drew and Hing-Po Lo[2]

[1]*Department of Building and Real Estate, The Hong Kong Polytechnic University, Kowloon, Hong Kong*

[2]*Department of Management Sciences, Hong Kong City University, Hong Kong*

In developing research methods for comparing contractors' bidding behaviour in different competitive environments, the central task is achieving reliable comparisons. In this paper discussion is concentrated on the designed bidding experiment that aimed to examine, in terms of decision to bid and mark-up decision, the extent to which individual Hong Kong and Singapore contractors are influenced, to varying degrees, by (1) market conditions, (2) number of bidders, (3) project type and (4) project size. This approach allows for a greater control over the manipulation of the bidding variables than would have been gained using real data, and in doing so make possible more direct comparisons between the two competitive environments (i.e. Hong Kong and Singapore). The research to date reveals that the experimental approach is well accepted by the Hong Kong and Singapore contractors in which useful data were obtained for subsequent analysis.

Keywords: bidding, experiment, research methods.

INTRODUCTION

The competitive environment is not static, nor the competition. Organizational theorist emphasizes that business organizations must adapt to their environment if they are to remain viable (Duncan 1972). With no exception of the construction firms, the behaviour of construction firms is strongly influenced by the environment within which they operate (Hillebrandt *et al*. 1995). The competitive environment within which contractors compete is seen by Newcombe (1990) as consisting of the (i) general environmental factors of politics and law, economics, sociology and technology and (ii) competitive environmental factors of finance, plant, labour, management, suppliers, subcontractors, consultants and clients. In addition, there are many bidding factors affecting contractors' bidding behaviour in terms of decision to bid and mark-up decision (Ahmad and Minkarah 1988; Odosute and Fellows 1992; Shash 1993). It follows that contractor's bidding decisions are dependent on individual firm-specific characteristics (e.g. competitive strategy, capability of management etc.) as evidenced in these studies where there are differences in ranking of factors that contractors consider when making decision in bidding competition.

To compete successfully, contractors not only need to have an understanding of the make up of different competitive environments within each country but also of contractors' competitive behaviour within those environments. The overall aim of this research project is to compare the bidding behaviour of contractors operating within

[1] beelan.oo@polyu.edu.hk

two different competitive environments (i.e. Hong Kong and Singapore). Within the context of four important bidding variables, i.e. market conditions, number of bidders, project type and project size (Skitmore 1989), the bidding experiment designed for data collection purposes is the focus of this paper.

Hong Kong (HK) and Singapore are chosen mainly on the basis of high *comparability* between the competitive environments in construction of these two city states (Oo and Drew 2005). Also, the designed bidding experiment is based on the conventional public sector building projects in HK and Singapore since they are *representative* and made up approximately 50% of the total construction demand in both industries (Oo and Drew 2005). In this way, reliable comparisons are promising in this research project by taking into account the two desired key elements of an international comparison study, i.e. comparability and representativity (Meikle 1990).

EXPERIMENTS IN CONSTRUCTION BIDDING RESEARCH

Fellows and Liu (2003: 84) define experiment as "an activity or *process*, a combination of activities, which produces *events*, possible outcomes". The basic intent of experimental research design is to allow researcher to control the research situation (or controlling for all other factors that might influence the outcome), so that one or more variables can be manipulated in order to test a hypothesis (Zikmund 2003). Research methods of experimental nature are not new in construction research. In particular, for studies of comparative nature such as comparing cost performance (Xiao and Proverbs 2002) and comparing price, methods and productivity (Edkins and Winch 1999; Proverbs *et al*. 1999) where the participants were required to response based on hypothetical projects, thus allowing the authors to control the research situation.

Experimental research in construction bidding may be traced as early as 1970. For example, Hackemer (1970) examined the effect of variability of estimate, number of competitors and mark-up on bidding strategy by asking five competitors to bid for 200 contracts. The bidding experiment, what the author refers to as 'simulation', has produced some 200,000 bids via application of different variability factors of estimate. Dyer *et al*. (1989), on the other hand, compared the naive and experienced bidders in the construction contract bidding in a laboratory experiment setting. This laboratory experiment does provide reasonable results as evidenced in their follow-up study via interviews and past bid data (Dyer and Kagel 1996). More recently, Drew and Skitmore (2006) used a bidding experiment to test the applicability of Vickery's revenue equivalence theory in construction bidding. Despite small sample size in this study with only six participants, appropriate procedures were used for selecting participants to enhance reliability and to keep their interest in the experiment that required them to bid for hypothetical projects over ten rounds.

Based on the classification framework suggested by Bowen (1978), the previous work using bidding experiments, variously termed as bidding games or simulations, in construction bidding research can be classified into one of three purposes: (i) learning (e.g. Harris and McCaffer 1989); (ii) teaching (e.g. Nassar 2003); and (iii) research (e.g. Hackemer 1970; Han and Diekmann 2001; Drew and Skitmore 2006). Although these previous work do have the potential to generate the data needed for this research, so many other issues would need to be considered. For example, the data from 'teaching' and 'learning' game formats are generally the products of specified lesson in the games and highly depend on the course of play, which cannot be specified in advance. In the last case, the research game is used as an empirical tool for investigating decision-making that allows controlled hypothesis testing. Han and Diekmann (2001) studied the contractors' risk attitude in the selection of international construction projects using a research game. Based on similar rationale, it was therefore decided to develop a controlled experimental design research game, i.e. a bidding experiment that specifically focuses on testing the effect of principal variables of interest on contractors' bidding behaviour.

The designed bidding experiment presented here was developed from a laboratory experiment on auction theory by Dyer (1987). It is worth noting that experiments have been remarkably successful in terms of extending the theoretical framework of auction theory. Kagel and Levin (2002) have devoted a whole volume to the experimental research in auction theory. It is argued that experimental approach is feasible to reveal some of the salient aspects of the complexities involved in construction bidding that would have been revealed using past-pooled bids or other forms of research design.

BIDDING EXPERIMENT METHOD

The 'after-only' quasi-experimental design (Zikmund 2003) is chosen for the bidding experiment. It involves an exposure of a group to an intervention followed by a measurement to determine the effect of the exposure. Although the quasi-experimental design does not qualify as true experimental design in a formal scientific sense due to its inadequacy to address potential threats to validity of an experiment (Creswell 2003), it is acceptable in construction management research due to impracticality of true experimental design (Fellows and Liu 2003). They go on to point out that it is neither practical nor possible to set up an experiment that is an exact replica of the commercial construction industry given that there are numerous independent variables on most occasions. For instance, Shash (1993) identified 55 factors affecting contractors' decision to bid. Thus, the usual approach is to adopt quasi-experimental design in which main independent variables, except the one of interest, are held approximately constant and the consequences for the major dependent variable are measured.

With respect to the four principal variables of interest, i.e. (1) market conditions, (2) number of bidders, (3) project type and (4) project size, the designed bidding experiment permits the following that justified its application:

- A direct comparison of contractors' bidding behaviour in terms of decision to bid and mark-up decision between the two city states.
- Generation of adequate sample that covers the region of interest of the principal variables (e.g. data sample for number of bidders scenarios ranging from 4 to 30), given that it is difficult to access real past bid data for projects of different type and size along with different market conditions and number of bidders.
- Examination of the effect of changing number of bidders on contractors' bidding decisions, as decision to bid and mark-up decision for several possible number of bidders scenarios are unobtainable in 'real world', where contractors only submit one-off bid in bidding for a project.
- Heterogeneous approach to modelling contractors' bidding decisions since a reasonable size dataset is obtained from each participant in the experiment.

The participants

Given that the focus here is on public sector contracting, the centralized contractors' registry systems maintained by the local government agencies were used as a basis in the selection of participants. All the (i) Group C contractors listed on the Hong Kong Environment, Transport and Works Bureau's (ETWB) List of Approved Contractors for Public Works (2005), and (ii) Groups A1, A2 and B1 general building contractors listed in the Singapore Building Construction Authority's (BCA) Contractors Registry (2005) were contacted for the research purposes. A review on past tender reports revealed that these groups of contractors are the 'active' market players in public sector general building contracting.

The procedures

The participants were invited to participate via email in the bidding experiment by (i) acting as senior managers of their construction firms; and (ii) bidding for 20 hypothetical projects. These were arranged in two rounds according to two extreme market conditions scenarios. The use of hypothetical projects removes the need to identify matching projects from HK and Singapore, and thus enhance the comparability of data collected. Project information from past tender reports by the local government agencies was used to give a broad but carefully worded description of the hypothetical projects in attempt to enhance representativity of data collected. The experiment requires the participants to draw upon their previous experience in deciding (i) which jobs to bid for and (ii) what mark-up should they apply to the job if they decided to bid.

Participants were informed that their ultimate aim is to survive and prosper in which lowest bidder will win the job. This was done to reflect the local industry norm that lowest bidder tends to win a job (Construction 21 Steering Committee 1999, Construction Industry Review Committee 2001). In attempt to establish a strong basis of comparison of results, a repeated-measures design was adopt for the experimental procedures in which the same 20 hypothetical projects were used in both rounds of the experiment. The sequence of the 20 projects, however, was randomly revised in the second round in order to avoid contamination of responses.

Manipulations of the principal variables of interest

The manipulations of the four principal variables of interest, in terms of values or levels that they assumed, are based on literature and previous empirical findings. Thorpe and McCaffer (1991) take the view that market conditions as an all embracing subjective terms which on a macro-(industry)level includes such factors: the total construction order for all work; the total orders for each market sector; projected future orders; current and projected governmental policy and legislation; construction price levels; cost of capital. On a micro-(company) level, it includes an assessment of contractors' local, national and international opportunities; competitor activity; volume of on-going work; and order books. Ngai *et al*. (2002) agreed that there is no definitive measure of market conditions in construction that exists in literature, with various variables employed including the ratio of tender price index to construction cost index, number of bids received for particular projects, and rate of change of a particular price index (e.g. tender price index). Prevailing market conditions oscillate between periods of economic boom and recession. It was therefore decided to set the two extreme market conditions scenarios as: (i) boom times with low need for work, and (ii) recession times with high need for work. This setting is closest in spirit to the work by de Neufville *et al*. (1977) in what they refer to as 'good' and 'bad' years where prevailing market conditions is seen as the proxy variable for the contractors' need for work. Participants were informed that all hypothetical projects could be completed within the stated boom and recession periods since larger project may extend over one or more phases of business cycle and contractors do anticipate likely future in their bidding decisions.

There are eight number of bidders scenarios (ranging from 4 to 30) for every hypothetical project with the *estimated* number of competing bidders, *N*, increasing in the levels of 4, 6, 8, 10, 14, 18, 24 and 30. This range of the number of bidders is determined based on recorded number of bidders per contract for HK and Singapore public sector general building contracts (Fu 2003; Oo and Drew 2005). The participants were asked to bid up to the bidding scenarios of *N* bidders that they wish to bid. This enables a close examination of bidding patterns when there is less number of bidders, and reduces the repetitive nature of the experiment since divergence in bidding decisions is expected to be less noticeable if there are too many bidders (Wilson *et al*. 1987). Also, the term 'estimated' was used because contractors are unlikely to have the exact number of competing bidders when submitting a bid.

The 20 hypothetical projects are of conventional type, i.e. new construction or rehabilitation works that involve buildings of usual design, and do not require any unusual construction technologies. This was done to control the effect of project type on contractors' bidding decisions since both the project type and complexity, to some degree, determines the potential group of competing bidders.

In terms of project size, the predetermined range of project size is based the participants' tendering limits set by the local government agencies for the perspective HK and Singapore participants. All the 20 projects selected are of size ranging from HK$ 50 to S$ 150 million (or S$ 10 to 30 million based on a conversion rate of S$ 1 to HK$ 5) in order to establish a competitive ground if the HK Group C, and Singapore Groups A1, A2 and B1 contractors are to compete.

So as the same project list can be used for these two city states to form a strong basis for comparisons, ten conventional projects that satisfied the selection criteria were selected from the past tender reports published by the HK and Singapore local government agencies, respectively. Project information of the selected projects was used to form a realistic baseline data for the construction of hypothetical project list used in the experiment. It should be noted that the wording of project description was changed as necessary to reflect the local bidding practices, for example, the term 'conversion and extension' and 'addition and alteration' were referred to upgrading and maintenance work in HK and Singapore, respectively. Also, the corresponding awarded contract values or lowest bid prices of the selected projects were used to compute the cost estimates for the hypothetical projects with necessary adjustments and updated to a common base date using published tender price indices.

To facilitate the participants' decision making, the cost estimate was (i) expressed in million of dollars, e.g. 55 million (instead of actual dollars) in respective local currencies, and (ii) defined in the experiment instrumentation as an 'unbiased estimate' of the net construction cost (i.e. contractors' in-house estimate) that includes the project preliminaries and site overheads, but without any adjustments for items such as general overheads, risk margins, competition, finance and profits.

The instruments

The instruments for the bidding experiment consist of a leaflet and two sets of bid response forms. As an alternative of a cover letter, an eye-catching colour-printed leaflet with a brief summary of this experimental research was first sent to the participants in seeking their voluntary participation in the experiment. This was done to seize their attention so as to increase the response rate. Indeed, the two-round nature of the bidding experiment had placed significant hurdles in recruiting participants.

Each participant were required to complete two sets of bid response form, each of different bidding (market conditions) scenarios. The bid response form consists of two parts, i.e. a single page of written instructions was presented in the first part, comprising assumptions, definitions and steps required to complete the bid response form, and the 20 hypothetical projects were listed in the second part of the bid response form. A copy of the bid response form is available from the author.

Controlling the extraneous variables

Apart from the information of the four principal variables, the participants were also given information on cost estimate, project duration, location, client and contract type to facilitate their decision making. Given that it is impractical for not including any extraneous variables in the experiment, a *constancy of conditions* was established in controlling these extraneous variables (Venkatesan and Holloway 1971 cited in Zikmund 2003). The basic intent of this procedure is to ensure that all the participants were exposed to situations that are exactly alike except for the differing conditions of the independent variables.

Threats to validity of the experiment

Experiments are judged by two measures: (i) internal validity – indicates whether the independent variable(s) was the sole cause of changes in dependent variable(s); and (ii) external validity – indicates the extent to which the results of the experiment are applicable in a real world situation, and whether the results can be generalized to the population it is meant to represent (Campbell and Stanley 1963). Table 1 summarizes the various measures designed to overcome the identified threats (Creswell 2002) to both internal and external validities of the bidding experiment.

Table 1: Adopted measures to overcome the threats to internal and external validities of the bidding experiment

Threats	Definition	Adopted measures
Internal validity		
• History effect	A specific event in the external environment occurring between 1st and 2nd measurements that is beyond the control of experimenter	A short interval was allowed between the repeated measurements, i.e. three weeks between the 1st and 2nd rounds of experiment
• Maturation effect	An effect caused by changes in experimental participants over time; it is a function of time rather than response to a specific event	Same as above
• Testing effect	An effect that occurred if identical instrument is used more than once	The sequence of the 20 projects was randomly revised in the second round of the experiment to avoid contamination of responses
• Instrumentation effect	An effect caused by a change in the wording, or other changes in procedures to measure the	A pilot test on the instruments used for the bidding experiment was

	dependent variable	carried out prior to data collection
• Selection effect	A sample bias or sample selection error	The selection of participants for the bidding experiment was based on the tendering limits set by the local government agencies
• Mortality effect	Sample attrition that occurs when participants drop-out during the experiment for any number of reasons (e.g. time, interest and money)	All the perspective contractors were contacted since it is very likely that some participants will drop-out after first round of the experiment. This was done to increase the number of complete response sets from the two rounds of the experiment
External validity		
• Interaction of selection and treatment	Inability to generalize beyond the groups in the experiment	The feasible measure to overcome this particular threat is to repeat the experiment with different samples, e.g. HK Group B contractors. If, however, the replication with this group of contractor gives rise to different results, it does not mean that the experimental procedure is flawed. Rather, it enables the experimenter to specify the limits of generalization and the groups of contractors to whom the results *do* and *do not* apply
• Interaction of setting and treatment	Inability to generalize from the setting where the experiment occurred to another setting	Similar to the above, replication is the possible strategy to draw the limits of generalization by conducting the experiment in different context, say, for private sector contracting along with different settings for the four independent variables
• Interaction of history and treatment	Inability to generalize findings to past and future situations	Likewise, replication is the possible strategy to draw the limits of generalization by conducting the experiment in different periods of time

Experiment limitations

Setting up a bidding experiment that is an exact replica of the commercial construction industry is extremely difficult, if not impossible. Given that there are so many possible factors affecting bidding decisions, the focus has therefore been on those key factors that comprise market conditions, number of bidders, project type and size. Other factors in the experiment including project duration, location, type of client and contract type have been held constant in establishing a setting that the subjects are familiar with, thus allowing their experience to manifest itself effectively.

The experiment, however, does not consider the direct effect of bidding decisions on future event since the 20 hypothetical projects were released at once. No feedback information were given to the subjects at the end of each round of the experiment as the two rounds of experiment are treated as independent study, based on different market conditions scenarios. It is felt that inclusion of 20 projects is necessary to generate a reasonable data set and to reflect that contractors are selective in their bidding decisions as bid enquiries are received continuously. Also, the participants tend to be more risk seeking in an experimental setting, although it is believed that industry practitioners who are willing to spend times on non-rewarding academic studies (in this case, two rounds of experiment) will respond genuinely since many stated they would do so.

CONCLUSIONS

In contrast to most published construction bidding work based on past-pooled bids, the research to date reveals that the experimental approach for data collection is well-accepted by the Hong Kong and Singapore contractors. In fact, the analysis undertaken at the time of writing shows that useful data were obtained for statistical modelling of the effect of (1) market conditions, (2) number of bidders, (3) project type and (4) project size on HK and Singapore contractors' bidding decision to bid and mark-up decision.

Replication of the bidding experiment method is feasible to reveal further some of the salient aspects of the complexities involved in construction bidding. For example, it is possible, through scenario building, to study the extent to which the (i) likelihood of claim back options, (ii) likelihood of follow-on project, and (iii) likelihood of post-tender negotiation would affect contractors' bidding behaviour. Data difficulties are anticipated in providing an insight on these phenomena, whereas other forms of research design appear to be inefficient or difficult to give an interpretation.

REFERENCES

Ahmad, I and Minkarah, I (1988) Questionnaire survey on bidding in construction. *Journal of Management in Engineering*, **4**(3), 229–43.

Bowen, K C (1978) *Research games: an approach to the study of decision processes*. London: Taylor & Francis.

Building Construction Authority (2005) *BCA contractors registry*. Singapore Government. Available online: http://dir.bca.gov.sg/bca/index.asp

Campbell, D T and Stanley, J C (1963) *Experimental and quasi-experimental designs for research*. Chicago: R. McNally.

Construction 21 Steering Committee (1999) *Construction 21*. Singapore: Ministry of Manpower and Ministry of National Development.

Construction Industry Review Committee (2001) *Construct for excellence: report of the Construction Industry Review Committee*. Hong Kong: Construction Industry Review Committee.

Creswell, J W (2002) *Educational research: planning, conducting, and evaluating quantitative and qualitative research*. New Jersey: Merrill.

Creswell, J W (2003) *Research design: qualitative, quantitative and mixed methods approaches*. 2ed. Thousand Oaks: Sage Publications.

De Neufville, R, Hani, E N and Lesage, Y (1977) Bidding models: effects of bidders' risk aversion. *Journal of Construction Division, ASCE*, **103**(CO1), 57–70.

Drew, D and Skitmore M (2006) Testing vickery's revenue equivalence theory in construction auctions. *Journal of Construction Engineering & Management*, **132**(4), 425–8.

Duncan, R B (1972) Characteristics of organizational environments and perceived environmental uncertainty. *Administrative Science Quarterly*, **17**(3), 313–27.

Dyer D (1987) An experimental analysis of auction theory, Unpublished PhD thesis, University of Houston.

Dyer, D and Kagel, J H (1996) Bidding in common value auctions: how the commercial construction industry corrects for the winner's curse. *Management Science*, **42**(10), 1463–75.

Dyer, D, Kagel, J H and Levin, D (1989) A comparison of naïve and experienced bidders in common value offer auctions: a laboratory analysis. *The Economic Journal*, **99**, 108–15.

Edkins, A and Winch, G (1999) *The performance of the UK construction industry: an international perspective*. Barlett Research Paper No. 4, London: University College London.

Environment, Transport and Works Bureau (2005) *List of approved contractors for public works*. The Hong Kong SAR Government. Available online: http://www.etwb.gov.hk/index_static.aspx

Fellows, R and Liu, A (2003) *Research methods for construction*. 2ed. Oxford: Blackwell Science.

Fu, W K (2003) *The effect pf experience in construction contract bidding*, Unpublished PhD Thesis, Department of Building and Real Estate, The Hong Kong Polytechnic University.

Hackemer, G C (1970) Profit and competition: estimating and bidding. *Building Technology and Management*, December, 6–7.

Han, S H and Diekmann, J E (2001) Making a risk-based bid decision for overseas construction projects. *Construction Management and Economics*, **19**(8), 765–76.

Harris, F and McCaffer, R (1989) *Modern construction management*. 3ed. Oxford: BSP Professional Books.

Hillebrandt, P M, Cannon, J and Lansley, P (1995) *The Construction Company In and Out of Recessio.* London: Macmillan Press.

Kagel, J H and Levin, D (2002) *Common value auctions and the winner's curse*. New Jersey: Princeton University Press.

Meikle, J L (1990) International comparisons of construction costs and prices. *Habitat International*, **14**(2/3), 185–92.

Nassar, K (2003) Construction contracts in a competitive market: C^3M, a simulation game. *Engineering, Construction and Architectural Management*, 10(3), 172–8.

Newcombe, R (1990) *Construction management 1: organisation systems*. London: Mitchell.

Ngai, S C, Drew, D S, Lo, H P and Skitmore, M (2002) A theoretical framework for determining the minimum number of bidders in construction bidding competitions. *Construction Management and Economics*, **20**(6), 473–82.

Odusote, O O and Fellows, R F (1992) An examination of the importance of resource considerations when contractors make project selection decisions. *Construction Management and Economics,* **10**(2), 137–51.

Oo, B L and Drew, D (2005) The bidding environments of Hong Kong and Singapore construction industries. *In*: Y Wang and Q Shen (Eds.) *Proceedings of 2005 International Conference on Construction and Real Estate Management*, Penang, Malaysia, Vol. 1, 65–70.

Proverbs, D G, Holt, G D and Olomolaiye, P O (1999) Productivity rates and construction methods for high rise concrete construction: a comparative evaluation of UK, German and French contractors. *Construction Management and Economics*, **17**(1), 45–52.

Shash, A A (1993) Factors considered in tendering decisions by top UK contractors. *Construction Management and Economics,* **11**(2), 111–18.

Skitmore, M (1989) *Contract bidding in construction*. Harlow: Longman.

Thorpe, T and McCaffer, R (1991) Competitive bidding and tendering policies. *In:* S Male and R Stocks (Eds.) *Competitive Advantage in Construction*. Oxford: Butterworth-Heinemann.

Wilson, O D, Atkin, A S, Sharpe, K and Kenley, R (1987) Competitive tendering: the ideal number of tenders. *In*: P R Lansley and P A Marlow (Eds.) *Managing construction worldwide*. London: E. & F. N. Spon, 175-86.

Xiao, H and Proverbs, D (2002) The performance of contractors in Japan, the UK and the USA: a comparative evaluation of construction cost. *Construction Management and Economics*, **20**(5), 425–35.

Zikmund, W G (2003) *Business research methods*. 7ed. Ohio: South-Western.

MEASURING COMPETITIVENESS IN THE CONSTRUCTION SECTOR – A NEW PERSPECTIVE

Roger Flanagan, Carol Jewell[1] and Weisheng Lu

School of Construction Management and Engineering, University of Reading, UK

There is no widely accepted definition of competitiveness and its measurement is complex, but measuring competitiveness remains an important goal for firms, industry and nations. This research sought to establish a method for measuring competitiveness that took account of the different perspectives of the stakeholders in the industry: clients, investors, design and construction enterprises, employees and society. Over 300 factors of competitiveness were identified through workshops, a Delphi study, interviews and a literature review. A framework was devised – the construction competitiveness hexagon (CCH) – for use at a national, industry and company level. The construction competitiveness toolbox (CCT) was produced: software that allows competitiveness to be measured using predetermined or customized factors relevant to the user(s). The main finding was not the competitiveness scores themselves from each of the three countries in the study but an understanding of the effect of different stakeholders' perspectives. Identifying, weighting and understanding the interdependency between the factors is crucial for the measurement of competitiveness.

Keywords: competitiveness, measurement, productivity.

INTRODUCTION

Globalization has created an interconnected and interdependent world. It converts the world into a complex and multi-faceted dynamic place with competition, trade, financial deregulation, growth of exports and imports and so on. Mobility of capital and an information and communications revolution has brought about time–space compression overcoming national boundaries. The effects can be seen in the UK construction sector with the rapid growth in imported construction components and materials, and the increase in UK companies, particularly design consultants, working overseas. To survive economically in this global marketplace, both companies and nations must be competitive, hence the importance of understanding the factors influencing competitive and comparative advantage.

OBJECTIVE

The objective of this paper is to give a new perspective on construction competitiveness by considering how construction competitiveness can be measured. It considers the development of a construction competitiveness toolbox that is computer aided and driven by organizations who want to measure some aspect of competitiveness.

[1] c.a.jewell@reading.ac.uk

THE CONCEPT OF COMPETITIVENESS

Competitiveness is high on the agenda for firms, industries and nations, but it is not well understood and has no common definition or metrics. There are many definitions:

> Competitiveness refers to a country's ability to create, produce, distribute and/or service products in international trade while earning rising returns on its resources. (Scott and Lodge 1985)
>
> Competitiveness is the degree to which a country can, under free and fair market conditions, produce goods and services which meet the tests of international markets while simultaneously maintaining and expanding the real incomes of its people over the longer term. (OECD 1997)
>
> Competitiveness is the ability of a country to create added-value and thus increase national wealth by managing assets and processes, attractiveness and aggressiveness, by integrating these relationships into an economic and social model. (International Institute for Management Development 1996)
>
> Competitiveness is about creating high skills, high productivity and therefore a high usage economy. (HMSO 1994)
>
> Competitiveness is the capacity of businesses, industries, regions, nations or supranational associations exposed, and remaining exposed, to international competition to secure a relatively high return on the factors of production and relatively high employment levels on a sustainable basis. (European Commission 1994)

The range of definitions indicates the complexity of the concept; there is no one definition accepted by all. The lack of consensus is due to diversity caused by different perspectives. The definitions tell us about the meaning of competitiveness and the factors involved, but they do not address the fundamental issue of how to measure competitiveness.

Competitiveness is not a zero-sum game. One country does not improve its competitiveness at the expense of other countries. The competitiveness of a national construction sector relates to the productivity, the intellectual capital, the core competencies, and the entrepreneurship and influence of a nation.

SUMMARIZING COMPETITIVENESS

Besides the various definitions, a number of other interesting characteristics are useful for gaining insights into the concept. They are:

Multi-defined: There is no general, generic definition of competitiveness and hence the term is subject to misinterpretation and consequent confusion (Porter 1990; Boltho 1996; Chaharbaghi and Feurer 1994; Lall 2001; Cho and Moon 2000).

Multi-measured: There is no single, generic measurement of competitiveness. Instead measurements vary with the definitions (Chaharbaghi and Feurer 1994; Buckley *et al*. 1988). More importantly, there is no standardized approach about how to measure the factors of competitiveness.

Multi-layered: Competitiveness may be applied to the national, industry and company levels (Momaya 2004; Lall 2001; Nelson 1992).

Dependent/Interdependent: Competitiveness depends on the values and the focus of the stakeholders of the entity under investigation (Momaya and Selby 1998; Chaharbaghi and Feurer 1994), and it will be influenced by a number of endogenous and exogenous factors.

Relative: Measurement of competitiveness needs to be looked at in a relative sense, either against some maximum ideal level, or against the peers in the sector (Chaharbaghi and Feurer 1994; Lall 2001).

Dynamic: The factors that influence competitiveness change with time and context, for example as a national economy moves from a less, to a more developed stage (Momaya 2004; Cho and Moon 2000).

Process: Competitiveness involves assets (human, financial and physical), processes and performance, where processes turn assets into performance (Buckley *et al*. 1988; Crouch and Ritchie 1999).

To summarize, the objective of competitiveness of nations centres on human development, growth and improved quality of life, while firm competitiveness is based more upon profitability, productivity and other business factors. Nations continually attempt to make cross-country comparisons. However, their competitiveness depends upon micro and macro economic factors in which a nation's firms compete.

Firm competitiveness is related to market performance, with productivity and the exploitation of knowledge capital being keys to success. The objective of firm competitiveness, after having secured survival, is the creation of profits and new growth options that create value and returns for shareholders. Hence, competitiveness is associated with achieving an objective. Competitiveness is not an end, but a means to an end (Buckley *et al*. 1988).

CONSTRUCTION SECTOR COMPETITIVENESS

Research on competitiveness conducted at Reading put forward a broad definition for competitiveness in the construction sector as the extent to which a business sector:

1. satisfies the needs of customers from the appropriate combination of the product–service characteristics such as price, quality, speed of delivery, certainty, innovation and reliability;
2. satisfies the needs of its constituents (stakeholders), for example, enterprises and workers in terms of wages, safe workplace, training, steady employment and pleasant work environment with career development;
3. offers attractive profits and return on investment, the potential for growth, with acceptable levels of risk;
4. satisfies the needs of society to be a responsible corporate citizen and to meet the needs of society in terms of pollution, energy conservation, sustainability and safe systems of working.

This definition differs from many others by recognizing the different stakeholders in the industry and their range of perspectives. Time is an important determinant in competitiveness. Most debates focus on past performance and assume that future performance will replicate the past. They adopt a longitudinal approach with a latitudinal measurement. A longitudinal approach is one that considers sustained competitiveness over time with all the stakeholders being satisfied.

FACTORS OF COMPETITIVENESS

Productivity is not the only factor of competitiveness. 'Productivity depends on the value of goods and services produced per unit of the nation's human, capital and natural resources, measured by the prices they can command in open markets and the efficiency with which they can be produced' (Porter 2002: 55). Productivity is about getting the best value from all inputs across the whole value chain. There needs to be sustained improvement in management, products and processes in component and materials manufacturing, design management and processes, site production and assembly.

Many factors make up competitiveness; each may be weighted differently when compiling an overall competitiveness 'score'. The following company competitiveness factors were identified from a literature review:

Price	**Productivity**
Intellectual property/competencies	Quality of management (profitability, seamless project delivery, speed of reaction)
Reputation for performance, reliability, and quality	Culture (underlying beliefs and behavioural manifestations)
Location and geographic representation	Size of turnover/strength of balance sheet
Availability of and access to resources – human, capital and natural	Innovation, research and development

Factors of national competitiveness are different (World Economic Forum 2002), they provide the framework in which a company operates:

Economic performance	**Business efficiency**	**Government efficiency**
Domestic economy	Productivity	Public finance
International trade	Labour market	Fiscal policy
International investment	Finance	Institutional framework
Employment	Management practices	Business legislation
Prices	Impact of globalization	Education
Infrastructure		
Basic infrastructure	Scientific infrastructure	Health and environment
Technological	Infrastructure	Value system

The list is not exhaustive, but it does provide a framework from which to base a measurement system for competitiveness.

MEASURING COMPETITIVENESS

Construction competitiveness cannot be measured by treating the construction sector as one industry. The sector can be classified into three distinct sub-categories because of the different mix of skills, capital and finance, and technology:

1. Manufacture and assembly of plant, equipment, components and raw materials – requires high capital and technology input. They can be manufactured anywhere and exported, as long as they are price competitive and meet the required codes and standards appropriate for the domestic market, and have the facility to support ongoing maintenance.

2. Professional design and consultancy services – mainly dependent on knowledge and intellectual capital and can take place in any country and be exported. The professional services are primarily dictated by the design codes, business and professional registration requirements and the cultural dimension of that country.
3. Site assembly/production carried out by contractors and specialist contractors – heavily dependent on organization and labour skills, plant, equipment and technology, use local labour (with culture and education and training variables), and experience local conditions (climate and geology variables). They frequently require companies to have a local presence or local partner.

Within the above groups, there are sub-groups. For example, housing contractors have very different organizational and business characteristics from those of civil engineering contractors. Housing contractors either work in social housing or they build speculatively for sale; they are focused upon the needs of the individual customer. They have a land bank which may stretch many years into the future; frequently this means large amounts of capital is locked up in land. The civil engineering contractor is generally dependent upon public sector organizations for workload. Projects involve using a lot of plant and equipment, and ensuring a project is cash positive as quickly as possible, using the client's money to fund the construction phase.

Therefore, when measuring the competitiveness of the firm, there must be an understanding of the different sets of factors of competitiveness of the business being considered. It is tempting to use the same factors throughout the sector, but these will not reveal the special characteristics of a country or a company.

THE READING RESEARCH

A research project (2004–06) undertaken by Reading University 'Measuring construction competitiveness in selected countries', funded by the EPSRC with matching industrial funding, considered construction industry competitiveness in the UK, Sweden and Finland. There was collaboration with the USA, Japan and Australia.

A four-step approach was used:

1. Undertake a literature review and consider the theoretical underpinning of competitiveness.
2. Identify the factors of construction competitiveness through workshops, Delphi study, focus groups and questionnaires.
3. Develop a model for construction.
4. Develop a tool for measuring competitiveness to be used at national, industry and firm level. The tool must be simple, adaptive, encourage lateral thinking, and be easy to operate for it to be used by the industrial community.

Step 1
A comprehensive literature review was conducted to understand the concept of competitiveness, the theoretical underpinnings, and its implications on the exploration of competitiveness factors. The literature review revealed extensive publications on competitiveness. None of the models was found to be a perfect match

for construction, but Porter's Diamond was considered to be the best fit and the most appropriate for adaptation; it proved to be the most robust and cross-disciplinary. As the starting point for developing a framework for the mapping of explanatory factors, it is important to consider the conclusions drawn by Ofori (2003). He suggests that 'in developing a model for analysing international construction, it would be relevant to consider the four determinants in Porter's diamond, as well as culture and institutional arrangements and government's influence. Chance would be an exogenous variable and there should also be an international dimension. Thus, each company's or industry's competitiveness would be depicted by a series of linked (national) diamonds' (Ofori 2003: 389). Interestingly, the construction industry was not the focus of any of the frameworks explaining competitiveness as discussed above, and thus it is likely that some special characteristics relevant to construction have not been taken into account.

Step 2

Over 300 factors of competitiveness were identified by the industry in all three countries. These factors were combined together on what was agreed to be a suitable level for a study on an industry level, ignoring the most detailed factors. Having eliminated the superfluous factors, a list of 158 factors remained. The different countries in the research focused on different priorities as being the most important factors. Finland regarded information and communication technology as being the key factor, whereas Sweden ranked this in the top 10 and the UK in the top 50. Sweden ranked the role of trade unions in negotiations as being in the top category, whereas Finland ranked it in the top 10 and the UK only in the top 100. The respondents in the sample were selected from different stakeholders, such as clients, government bodies, trade unions, design consultants, contractors and the supply chain. In every case, safety and human resource issues ranked very highly in the factors of competitiveness.

Step 3

A construction competitiveness hexagon was developed based on Porter's Diamond. Adaptations were made to the Diamond: Related and supporting industries was left out (due to the multi sub-group nature of the construction sector), Context for firm strategy and rivalry was split into Firm strategies, management and organization and Industry characteristics; Government was moved from being an exogenous determinant to being part of the hexagon, and Factor conditions were split into Human resources and Factor conditions. These changes were based on the literature (Cho 1994; Lall 2001; Stopford and Strange 1991; van den Bosch and de Man 1994) and data from interviews and workshops in Finland, Sweden and the UK. Figure 1 shows the construction competitiveness hexagon, its six faces and culture and chance which impact on all these.

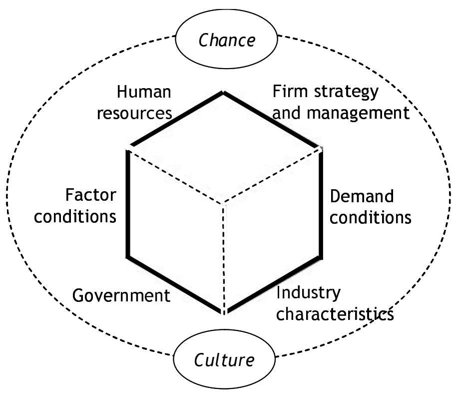


Figure 1: The construction competitiveness hexagon

For simplicity, the hexagon can be considered as a cube; on each face of the cube there are factors that influence performance and competitiveness. For example under 'Firm strategies and management', the following factors were identified from the data; the list is not exhaustive, it is intended to illustrate the principles involved:

Corporate
- Risk management
- Business ethics
- Environmental awareness
- Change management
- Attitudes and priorities towards new technology
- Labour/capital balance
- Level of R&D investment

Project
- Ability to create financial solutions for clients and projects
- Ability to give financial guarantees to clients
- Lean production in construction
- Production process
- Standardization of the production process (design, materials and work methods)
- Health and safety
- Conflict in contracts
- Use of IT in design and production

Various approaches to measurement were considered, including the analytical hierarchical process (AHP) and analytical network process (ANP) and Bayesian networks, which let us understand an event by gathering qualitative and quantitative data on its causal factors and mapping the relations between them. Until recently, there was neither the theoretical framework, nor the means to analyse such 'messy' statistical integration problems. Modelling the causal factors determining construction industry competitiveness presents enormous methodological challenges. For some factors (e.g. productivity), statistically valid quantitative data from industry and government sources are available. For others (e.g. human resource performance), it was necessary to draw on primary or secondary sourced qualitative data (principally expert opinion). For many factors questionable or sparse quantitative data were integrated with expert opinion.

Step 4

A construction competitiveness toolbox (CCT) was devised based upon the competitiveness hexagon providing the user with a number of ways of looking at the factors of competitiveness and the measurement. The CCT can be used at the national level to compare countries, or by companies to assess their competitiveness. The toolbox is sufficiently flexible for a company to allow competitiveness factors that are important to each firm to be considered in a methodical way. This is done through the toolbox's six matrices, under the headings used in the construction competitiveness hexagon.

The first step is the selection of the factors of competitiveness which can either be from a predefined list or a company can produce a unique list of factors. The CCT can be used at all levels of the business, from top management to a project team. From a long list generated by the selection system, the top factors are entered into the appropriate matrix in the program.

A weighted evaluation matrix allows the user to rank the factors against each other, with a weighting that is based upon subjective judgement. There is no hard science to the measurement, it is opinion based. The result of determining the importance of each factor relevant to another factor becomes the raw score in the matrix on a scale 1–100 – see Figure 2. The scoring is attempting to prioritize each of the factors by using a raw score; the next step is to look at the performance of each of those factors.

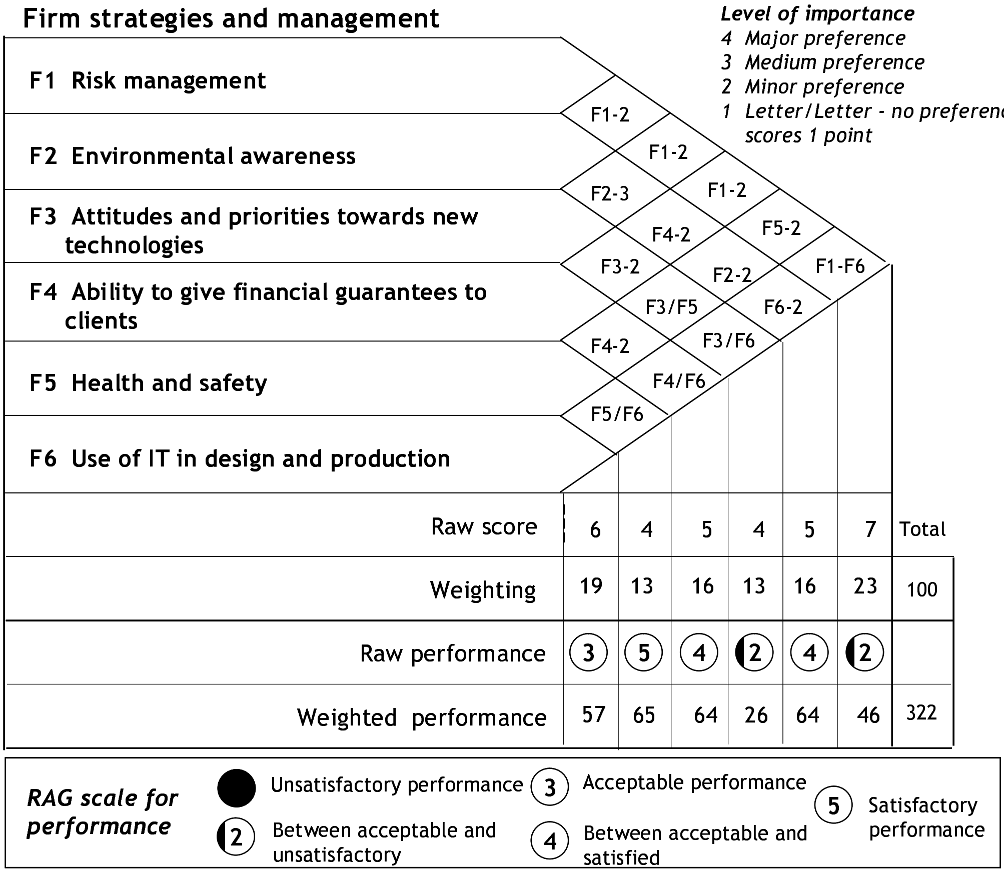


Figure 2: The weighted evaluation matrix used for the relative importance of factors within the firm strategies and management determinant

A five-point scale is used, based on the RAG (red–amber–green) scale ranging from unsatisfactory to satisfactory – see Figure 2. The selected top factors are generated in the left hand side of the matrix. These are compared to each other, by the group using a preference scoring system. For example, comparing the importance of F1 (Risk management) to F2 (Environmental awareness) F1 is moderately preferred to F2. In the same way, a comparison between F2 and F3 (Attitudes and priorities towards new technologies) results in a moderate to strong preference for F2.

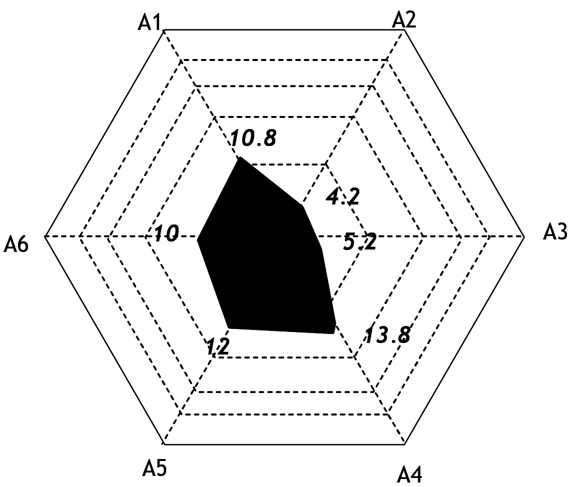


Figure 3: The hexagon produced from the weighted evaluation matrix for each determinant, giving the total competitiveness score

Once the matrix has been completed the program automatically produces the raw scores and importance levels. The next step is to assess the performance of each of the factors at a company/project level, allowing the program to calculate the weighted performance.

The program then calculates the competitiveness score and produces a ‘spider’ diagram, shown on the left hand side of the screen shot in Figure 3. This not only allows the results to be graphically seen, but also allows comparisons to be made if the process is undertaken by different people or at different times. The figures on the right hand side are further graphic representations of the results.

SUMMARY OF CCT

The flexibility of the CCT is important with the changing environment of construction and global business. The impact of factors of competitiveness will change over time and is relevant to geography. For example the factors chosen by a project team for an office development in Manchester will be very different from those selected for a multi-million pound hotel complex in Dubai.

Company strategies change over time and the CCT can reflect this, allowing different sets of factors to be used at different times. The graphical nature of the output is easy to understand and does not require the user to have a great deal of computer expertise. The hexagon output allows easy comparisons to be made of ‘results’ from different time periods or, if appropriate, from an analysis of competitors.

CONCLUSION

Competitiveness is a complex issue; it is much more straightforward to measure the factors of competitiveness at the firm level rather than at industry or national level. While there was general agreement across the UK, Swedish and Finnish construction sectors on the factors of competitiveness, views on the measurement of the factors varied according to the level of importance each country placed on them. It was evident that a computer-assisted toolbox was required to provide both a structure and a range of alternatives that could be used at the three levels – national, industry and firm.

The CCT toolbox developed allows the user to recognize the interdependency between the factors of competitiveness and customize the choice of factors according to the business, the market or a project strategy. Its flexibility allows it to be used in all spheres of construction. The toolbox is at its early stages of development, ongoing research and dissemination will help to refine and improve it to meet the needs of its users. It has been tested and validated in practice with consistent and reliable results.

The CCT is a practical tool emanating from academic research thus bridging the gap between theory and practice.

REFERENCES

Boltho, A (1996) The assessment: international competitiveness. *Oxford Review of Economic Policy*, **12**(3), 1–16.

Buckley, P J, Pass, C L and Prescott, K (1988) Measures of international competitiveness: a critical survey. *Journal of Marketing Management*, **4**(2), 175–200.

Chaharbaghi, K and Feurer, R (1994) Defining competitiveness: a holistic approach, *Management Decision*, **32**(2), 49–58.

Cho, D-S and Moon, C-H (2000) *From Adam Smith to Michael Porter: evolution of competitiveness theory*. Singapore: World Scientific Publishing Company Ltd.

Crouch, G I and Ritchie, J R B (1999) Tourism, competitiveness and societal prosperity. *Journal of Business Research*, **44**(3), 137–52.

European Commission (1994) *Growth, competitiveness, employment*. Luxembourg: European Commission.

HMSO (1994) *Our competitive future: building the knowledge driven economy*. UK White Paper on competitiveness. London: HMSO.

International Institute for Management Development (1996) *World competitiveness yearbook.* Lausanne, Switzerland: International Institute for Management Development.

Lall, S (2001) *Competitiveness, technology and skills*. Cheltenham, UK: Edward Elgar Publishing.

Momaya, K (2004) Competitiveness of firms: review of theory, frameworks, and models. *Singapore Management Review*, **26**(1), 45–61.

Momaya, K and Selby, K (1998) International competitiveness of the Canadian construction industry: a comparison with Japan and the United States. *Canadian Journal of Civil Engineering*, **25**, 640–52.

Nelson, R (1992) Recent writings on competitiveness: boxing the compass. *California Management Review*, Winter, 127–37.

OECD (1997) *Industrial competitiveness: benchmarking business environments*. Paris: OECD.

Ofori, G (2003) Frameworks for analysing international construction. *Construction Management and Economics*, **21**, 379–91.

Porter, M (1990) *The competitive advantage of nations*. London: Macmillan.

Porter, M (2002) Enhancing the microeconomic foundations of prosperity: the current competitiveness index. *In*: *World Economic Forum world competitiveness report, 2001–2002*. Geneva: Oxford University Press.

Saaty, T L (1990) *Multicriteria decision making: the analytic hierarchy process*. Pittsburgh PA: RWS Publications.

Saaty, T L (2001) *Decision making with dependents and feedback: the analytic network process*. Pittsburgh, PA: RWS Publications.

Scott, B R and Lodge, G C (1985) *US competitiveness in the world economy*. Boston: Harvard Business School Press.

Stopford, J M and Strange, S (1991) *Rival states, rival firms: competition for world market shares.* Cambridge: Cambridge University Press.

Van den Bosch, F A J and de Man, A P (1994) Government's impact on the business environment and strategic management. *Journal of General Management*, **19**(3).

WEF (2002) *The global competitiveness report*. Geneva: World Economic Forum.

ECONOMICS OF INCORPORATING EARTHQUAKE RESISTANT PROPERTIES INTO RESIDENTIAL BUILDING DEVELOPMENT IN JORDAN

Ghaleb J. Sweis,[1] Rateb J. Sweis,[2] Anis S. Shatnawi[1] and Nazzal S. Amouti[1]

[1]*Civil Engineering Dept, University of Jordan, Amman, Jordan*
[2]*Amman Arab University, Amman, Jordan*

Due to the rapid urban development process in the last two decades, Jordan's vulnerability to earthquakes has increased. This research assessed the direct cost of structural mitigation and expected damage to a typical five-storey apartment building in case of an earthquake in Jordan. Cost estimates for the typical reinforced concrete building were calculated before and after applying the 2005 Jordanian Seismic Design Code. In addition, the Turkish Damage Probability Matrices were adopted to assess the magnitude of earthquake damage. The cost of incorporating earthquake resistance against collapse and subsequent loss of life was estimated at 1.63% of the capital cost of building. This is likely to prove of significant financial benefit, making the actual incorporation of earthquake vulnerability reduction strategies into public policy a sound decision.

Keywords: construction design, cost-benefit, earthquakes, Jordan, structural mitigation.

INTRODUCTION

Disasters, whether natural or man-made, have serious long-term negative impacts on the development of a community. A relatively small, single investment in disaster preparedness or mitigation can greatly reduce the recurrent losses of capital items and production caused by disasters. However, in any development program there will be competition for resources and priorities need to be set. Of particular interest here are the techniques and methods by which decision-makers compare development alternatives. There are ranges of models, which represent the ways in which comparisons are made in development decision-making. Politicians rarely view mitigation with much favour. Short-term considerations tend to dominate and mitigation often has little mass-appeal in electoral terms. For many populations, the main concern is with day-to-day survival and this is inevitably reflected in the political arena. In many countries, disasters occur rather infrequently, and it is perhaps understandable that some politicians and government officials usually discount the possibility of having to justify a lack of expenditure on mitigation. In addition, if a disaster does occur, there is always the perceived benefit of "putting on a show" of large-scale relief, however ineffective it may be (Dowrick 1987).

Mitigation within the framework of sustainability involves long-term planning of multiple objectives. It aims to improve the living conditions of the poor and to safeguard the environment, while meeting needs of current and future generations. Approaches to sustainable mitigation of natural disaster acknowledge that natural

[1] gsweis@ju.edu.jo

processes and human activities interrelate to produce disasters and that most of the issues and solutions are therefore also interrelated. Therefore, a solution to one problem can meet more than one goal or need (Sirleaf 1993).

The country of Jordan recently experienced a boom in the construction sector as a result of rapid population growth as well as regional political developments. The construction processes of many residential apartment and office buildings are applied with little attention to ethical standards and comprehensive national design codes and practices. Consequently, populations are exposed to ‘unsafe conditions’ in which a fragile physical environment and local economy unite with the overall shortcomings of a vulnerable society to prevent disaster mitigation and preparedness.

This research aims at raising the question about Jordan’s increased vulnerability to earthquakes and moving further towards the goal of developing means to deal with this phenomenon. Namely, determination of the direct cost of structural mitigation, damage to a typical building in case of an earthquake, and how many earthquake-incurred damages can be avoided per unit time.

LITERATURE REVIEW

UNDP- DHA (1994) suggests that there are two main aspects to this relationship between development and vulnerability to disaster: a positive one and a negative one. According to this analysis, which is also supported by Sirleaf (1993), the relationship between community development and vulnerability to disasters can be summarized under four headings (see Figure 1).

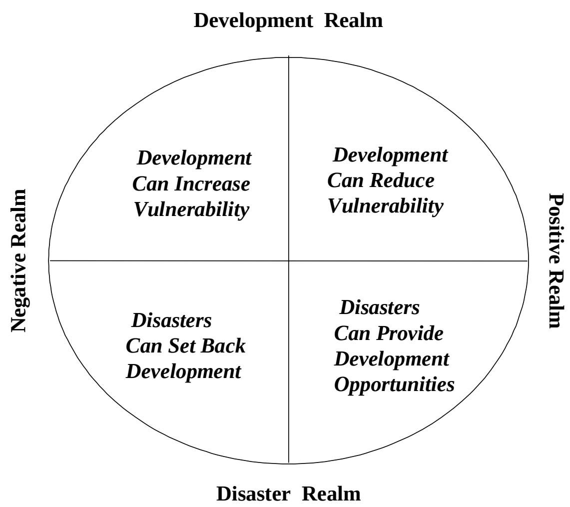


Figure 1: The relationship between development and vulnerability to disasters (UNDP-DHA 1994)

According to Ozwedem and Barkat (2000) in their article entitled “After the Marmara earthquake: lessons for avoiding short cuts to disaster”, the context of the close-woven relationship between disasters and a society’s social, economic, political and physical vulnerabilities has been explored by Quarantelli (1978), Davis (1978, 1986), Anderson and Woodrow (1989) and Blaikie *et al*. (1994). They all agree that a disaster occurs when its two main components, hazard and vulnerability, coincide in time and place.

Based on this argument, Blaikie *et al*. (1994) proposed the concept of a pressure and release model for disasters, which presents the progression of vulnerability from root causes to unsafe conditions. Development requires institutional and structural transformations of societies to speed up economic growth, reduce levels of inequality, and eradicate absolute poverty. Over time, the effects of disasters can seriously degrade a country's long-term potential for sustained development and cause governments to substantially modify their economic development priorities and programs.

In conjunction with the preceding argument, a number of mitigation strategies in parallel can be employed to ensure urban safety against disaster. Strategies can include structural measures and non-structural measures. Structural measures would reduce the impact of disasters and non-structural measures would enhance the management skills and improve capacities of the community, local self-governments, urban bodies and the State authorities to prepare, prevent and respond effectively to disasters. Non-structural measures include vulnerability mapping, risk assessment analysis, hazard zoning, inventory of resources to meet the emergency, knowledge networking of best practices etc.

RESEARCH METHOD

This research proposes a framework for developing a methodology to assess the benefits of direct cost of mitigation and damage to a typical five-storey building in Amman, Jordan. The focus of this research will be on structural measures to reduce the impact of disaster. Cost estimates will be made using the Construction Specification Institute's Master Format. Namely, the specification writing standard for most commercial building design and construction projects in North America and is currently adopted by many firms in Jordan.

Building on the findings of Yucemen (2005) stating that, due to the uncertainties involved, the damage that may occur during future earthquakes in Jordan has to be treated in a probabilistic manner, Damage Probability Matrices (DPM) are constructed from observational and estimated data. A DPM expresses what will happen to buildings, designed according to some particular set of requirements, during earthquakes of various intensities. It is necessary to obtain the DPMs that are applicable for the seismic zone in which Amman city is located. Since it was not possible to obtain these DPMs directly for Jordan, other sources of information have to be used. For this purpose, the research utilizes the DPMs developed for the four different seismic zones of Turkey by using both empirical results and subjective judgment of experts (Yucemen 2005).

DETERMINATION OF DIRECT COST OF MITIGATION

The vast majority of Jordan's urban population today lives in five-storey apartment blocks constructed of reinforced concrete similar to the one considered in this research. The research utilizes a design strategy that applies the 2005 Jordanian Seismic Design Code for Buildings to a typical five-storey reinforced concrete building. The structural system of the building for both vertical and lateral load systems consists of a dual system in both directions. The system considers ordinary shear wall elements coupled with ordinary reinforced concrete moment-resisting frame elements. Both elements are designed and detailed according to ACI-318 standard, release 2002.

The new Code is intended to provide designers with the required provisions for the "performance-based" seismic analysis and design of new structures. It is important to understand that seismic codes result in earthquake resistant buildings rather than earthquake-proof buildings. Their purpose is to protect life safety by preventing building collapse and allowing for safe evacuation. The contents and interiors of buildings, even those of well-designed buildings, may receive extensive damages and critical functions of a building may cease. Also, structural damage may occur from major earthquake ground-shaking. Structures built according to the new Jordanian Code for Earthquake-Resistant Buildings should:

1. Prevent frequent structural and non-structural damage in frequent minor ground shaking.
2. Prevent structural damage and minimize non-structural damage in occasional moderate ground shaking.
3. Avoid collapse or serious damage in rare major ground shaking.

Generally, structures that are designed and constructed in conformance with the code requirements are expected to encounter earthquake related structural damage (Al-Nimry and Kahhaleh 2005).

For the typical five-storey building in Amman, Jordan, the cost of incorporating earthquake resistance against collapse and subsequent loss of life is estimated at 1.63% of the capital cost of building (see Table 1). This finding supports a study conducted by the Building Seismic Safety Council (BSSC) in 1985 where they contracted seventeen design firms from nine US cities to perform two designs for each of several typical building types, first using the existing local code and then using the seismic provisions. They found the average increase in total costs to be 0.7% for low-rise residential buildings, 3.3% for high-rise residential buildings, 1.3% for office buildings, 0.5% for industrial buildings, and 1.7% for commercial buildings. Cities with previous seismic design provisions in their codes averaged much smaller cost increases (0.9%) than did cities with no seismic codes at all (Building Seismic Safety Council 1985.)

DETERMINATION OF DAMAGE TO THE BUILDING

In the context of this analysis, the severity of earthquake is expressed in terms of peak ground acceleration (PGA). The damage to the building from earthquakes of different PGAs is then to be estimated based on fragility curves. The fragility curves of a particular building provide the probability of exceeding different levels of damage (e.g. slight, moderate, major, collapse) as a function of the level of shaking. Fragility curves can be determined either empirically using damage data from past earthquakes or by numerical analysis.

Unfortunately, at this time, for the country of Jordan, no fragility curves for a representative structure are available. The computation of earthquake damage requires information on future earthquake hazard and expected earthquake damage on engineering structures, which are not readily available in Jordan.

Table 1: Direct cost estimates for the sample five-storey building in Amman, Jordan

Div. No.	Proposed Area = (2140 M2)	Typical Design			Seismic Design		
	Description	**Rate/M2 $**	**Amount $**	**%**	**Rate/M2 $**	**Amount $**	**%**
2	Site work	11.30	24,181	3.32%	11.30	24,181	3.27%
3	Concrete	93.22	199,491	27.39%	98.87	211,582	28.57%
4	Masonry	35.31	75,565	10.37%	35.31	75,565	10.20%
5	Metals	14.12	30,226	4.15%	14.12	30,226	4.08%
6	Wood and Plastic	N/A	N/A	N/A	N/A	N/A	N/A
7	Thermal and Moisture Protection	24.01	51,384	7.05%	24.01	51,384	6.94%
8	Doors and Windows	31.07	66,497	9.13%	31.07	66,497	8.98%
9	Finishes	42.37	90,678	12.45%	42.37	90,678	12.24%
10	Specialties	1.41	3,023	0.41%	1.41	3,023	0.41%
11	Equipment	N/A	N/A	N/A	N/A	N/A	N/A
12	Furnishings	N/A	N/A	N/A	N/A	N/A	N/A
13	Special Construction	N/A	N/A	N/A	N/A	N/A	N/A
14	Conveying System	16.95	36,271	4.98%	16.95	36,271	4.90%
15	Mechanical Works	42.37	90,678	12.45%	42.37	90,678	12.24%
16	Electrical Works	28.25	60,452	8.30%	28.25	60,452	8.16%
	Sub-Total	340.40	728,446	100%	346.05	740,537	100.00%

This research utilizes the DPM's developed for Turkey's four different seismic zones. There are five levels of damage states. The damage ratio (DR) is defined as the ratio of the cost of repairing the earthquake damage to the replacement cost of the building. For mathematical simplicity, it is convenient to use a single DR for each damage state (DS). This single DR is called the central damage ratio (CDR) (see Table 2).

Table 2: Damage probability matrix (Yucemen 2005)

Damage State (DS)	Damage Ratio (DR) %	Central Damage Ratio (CDR) %

None	0–1	0
Light	1–10	5
Moderate	10–50	30
Heavy	50–90	70
Collapse	90–100	100

ANALYSIS OF THE ECONOMICS OF SEISMIC MITIGATION

Is it worth it? This is the primary question about seismic mitigation to reduce expected damages and casualties from future earthquakes. Decision-making about the prospective seismic mitigation in new apartment buildings in Jordan may be difficult due to lack of estimates of the benefits (i.e. avoided future damages, losses and casualties). In many cases, life safety (avoiding casualties) is the principal motivation for implementing seismic mitigation, while in some instances property protection or continued functionality of important services may be the driving economic force.

The research will employ estimates of the benefits by answering the following question: is it cost effective to incorporate earthquake resistance in residential building in Amman, Jordan?

After some reflection on the above question, one could reasonably contend that incorporating earthquake resistance in residential buildings leads to an incremental increase in investment costs. Benefits are in term of reduced chance of future damages and causalities.

Additional assumptions needed during the analysis of the situation include:

- Since it was not possible to obtain DPMs directly for Jordan, other sources of information have to be used. For this purpose, the DPMs developed for the four different seismic zones of Turkey by using both empirical results and subjective judgment of experts.
- A building useful life (N) of 50 years with repeatability and the Discount Rate (i) of the Federal Emergency Management Agency (FEMA) of 7% will be used (FEMA 1997).
- In the event of a severe earthquake, cost of fatalities will not be considered, only the direct cost of the physical damage to the building.

Selecting the dollar as the common unit of measure. The annual cost of incorporating earthquake resistant (A) can be calculated:

(A) = P (A/P, i%, N)

Where P is the additional cost of $ 12091.00 associated with incorporating earthquake resistance (see Table 1) and (A/P, i%, N) is the capital recovery factor where i=7% and N= 50 years.

From the above equation, A = $877.00/year

Table 3 depicts the expected damage cost in (US$) of not incorporating earthquake resistant. The ratio of the cost of expected damage to the annual cost of incorporating earthquake resistant reveals the number of years in which an earthquake related structural damages can be avoided. In the event of minor ground shaking, if incorporating earthquake resistant will result in at least one earthquake –incurred damages being avoided during the next [$37000.00/($877.00/year)] = 42 years, then the mitigation is cost effective. Although in the short term, it can be contended that mitigation leads to increased cost, the benefits of increased personal safety and mitigation of possible damage costs in the long-run more than offset the apparent short-term cost savings.

Table 3: Cost of damage/damage probability matrix

Damage State (DS)	Damage Ratio (DR) %	Central damage ratio (CDR) %	Cost of expected damage (in thousands of dollars)
None	0–1	0	0
Light	1–10	5	37
Moderate	10–50	30	222
Heavy	50–90	70	518
Collapse	90–100	100	741

Furthermore, the benefits are underestimated because they do not account for the benefits of reducing fatalities, injuries, fire potential or economic losses. This research provides valuable analytic support to the claim that incorporating earthquake resistance in residential buildings is cost-effective, even in the event of minor ground shaking.

CONCLUSIONS AND FURTHER RESEARCH

Horrific images of recent disasters demonstrate the importance of shifting from post-disaster emergency actions to pre-disaster mitigation. To reduce population’s vulnerability to earthquakes, Jordan needs to examine its strengths and weaknesses, build on the strengths, and systematically take actions, which can reduce or eliminate the weaknesses.

Earthquake damage can range from minor damage to non-structural elements, which often does not exceed 2% of the value of the building, to more major damage of structural elements, which will require the relocation of the occupants while repairs are carried out. In the extreme, the total loss of the building, leading to its demolition, may occur. Damage can therefore range from less than 2% to more than 100%. Considering consequential losses, the cost of including earthquake-resistant features into a building’s design (usually less than 2% of the initial construction costs) is therefore likely to prove of significant financial benefit.

Adding to these benefits is the logical connection between adopting mitigation measures in advance and the claims costs from insurance should an earthquake occur. Balamar (2001) and Gulan (2001) highlighted this importance by citing previous experience with earthquakes in Turkey.

Ensuring the preservation of life is equally important to the occupants of the building. It is not usual to place a financial value on the "peace of mind" of the occupants, nor on the personal and financial losses incurred from injury or loss of life. However, this is an important consideration to the macro-economic framework of a country. The prevention of dislocation to businesses and individuals will impact on the time taken for the country’s economy to return to normal.

REFERENCES

Al- Nimri, H and Kahhaleh, Kh (2005) The Jordanian Code for Earthquake-Resistant Buildings. *In: Proc. The International Earthquake Engineering Conference*, 21–24 Nov, Dead Sea Jordan.

Anderson, M and Woodrow, P (1989) *Rising from Ashes: Development Strategies in Times of Disaster*. Paris: UNISCO.

Balamir, M (2001) Recent Changes in Turkish Disaster Policy: A Strategic Reorientation? *In:* P Kleindorfer and M Sertel (Eds.) *Mitigation and Financing of Seismic Risks: Turkish and International Perspectives*. Dordrecht: Kluwer Academic Publishers.

Blaikie, P, Cannon, T, Davis, I and Wisner, B (1994) *At Risk: Natural Hazards, People's Vulnerability and Disasters*. London: Routledge.

Building Seismic Safety Council (1985) *Societal Implications: Selected Readings*, FEnIA #84, June.

Davis, I (1978) *Shelter after Disaster*. Oxford: Oxford Polytechnic Press.

Davis, I (1986) Lessons from Reconstructions after natural Disasters for Cities Recovering from Bombing and Civil Strife. *In: Proc. of an International Conference on Reconstruction of the War-Damaged Areas*, March, University of Tehran.

Dowrick, D (1987) *Earthquake Resistant Design for Architects & Engineers*. 2ed. New York: John Wiley and Sons.

FEMA (1997) *Guidelines for Seismic Rehabilitation of Buildings*. Washington DC: Federal Emergency Management Agency.

Gulan, P (2001) Rebuilding the Sea of Marmara Region: Recent Structural Revisions in Turkey to Mitigate Disasters. *In*: A Wharton, *World Bank Conference on Challenges in Managing Catastrophic Risks: Lessons for the US and Emerging Economies*, Washington, DC.

Ozwedem, A. and Barkat, S (2000) After the Marmara earthquake: lessons for avoiding short cuts to disaster. *Third World Quarterly*, **21**, 425–39.

Quarantelli, E (1978) *Disasters: Theory and Research*. Oxford: Sage.

Sirleaf, E (1993) From Disaster to Development. *In*: K Cahill (Ed.) *A Framework for Survival: Health, Human Rights and Humanitarians Assistance in Conflicts and Disasters.* The Council of Foreign Relations. New York: Basic Books.

UNDP-DHA (1994) *Disasters and Development,* prepared by RS, Stephenson Disaster Management Programme, UNDP.

Yucemen, M (2005) Probabilistic Assessment of Earthquake Insurance Premium Rates For Jordan. *In: Proc. The International Earthquake Engineering Conference*, 21–24 Nov, Dead Sea Jordan.

THE STUDY OF USING AHP AND FUZZY MCDM FOR THE STRATEGY OF SUBCONTRACTOR SELECTION

Chun-Nen Huang[1], Shih-Tong Lu[2] and Yao-Chen Kuo[3]

[1]*Department of Security Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*
[2]*Department of Risk Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*
[3]*Department of Property Management, Kainan University, No.1, Kainan Road, Luzhu, Taoyuan County, 33857 Taiwan*

Subcontracting is the most prevailing means employed by a general contractor to execute a project. For a general contractor, how to select a set of good subcontractors to complete all the construction activities is one of the crucial strategic decisions in business administration. This study is to develop an objective system to help the general contractor select qualified subcontractors, which is crucial to a project success. The factors to select the subcontractors are investigated by questionnaires and interviews. Furthermore, by means of both Analytic Hierarchical Process (AHP) and Fuzzy Multiple Criteria Decision Making method, a quantitative selection system, which includes the evaluation factors and weights, is developed for the general contractor to select his subcontractors objectively.

Keywords: subcontractors selection, AHP, Fuzzy MCDM.

INTRODUCTION

The construction industry is the one that brings about the development of other industries and is always regarded as the “locomotive industry”. Further analysis shows that the parties involved in construction projects are architecture firms, engineering consultant companies, insurance companies, real estate owners (the government or the private enterprises), law firms, the stakeholders from real estate industry and banking industry, and so on. Among them, the parties with a direct relationship to a construction project are real estate owners, designers’ sectors (architectural companies, engineering consultant companies), general contractors, and subcontractors. The cost during the construction stage occupies over 90% of the total cost of a construction project and the general contractor is always fully responsible for the overall performance at the construction stage.

With the trend of specialization, general contractors have switched from the traditional emphasis on substantial construction technology to the management-based model. The main roles managed by the general contractor are the different kinds of subcontractors (or the collaborating business firms or small contractors, which are generally divided into four kinds: material suppliers, manpower subcontractors, manpower-and-material subcontractors, and mechanical work subcontractors) engaged in specialized production. Hence, the construction skills of subcontractors and the extent of their cooperation with the general contractor are directly and significantly correlated to the

[1] cnhuang@mail.knu.edu.tw

performance of a construction project in terms of quality, production rate, cost and safety. In other words, the means to strengthen the connection between two production units, the general contractor and the subcontractors, is a significant step towards improving the project quality and construction productivity.

In the entire construction process, a close relationship has to be maintained between the general contractor and the subcontractors. Such a business relationship starts from the selection of the right subcontractors, extends at the stage of construction and inspection and then the performance evaluation of subcontractors, and ends at the guarantee period. Whether qualified subcontractors are chosen by the general contractor at the selection stage of construction projects will impose critical effects on the incentive schedule and the quality of a project. Having made preliminary interviews with several contractors and gathered some information from them, the study finds that although general contractors have certain procedures of selecting subcontractors, uncertainties or the lack of objectivity exist in the evaluation criteria, making the general contractors too much dependent upon (such as quotations of business firms) or neglect certain indicators (such as quality control ability), and consequently leading to a conflicting collaboration, or even resulting in the failure of the project. In view of this, the study carries two purposes:

1. To understand the transaction process and problems between the general contractor and the subcontractors, particularly concerning the selection of subcontractors.
2. To analyse the general contractor's selection factors of subcontractors, and establish the objective indicators.

ESTABLISHMENT OF SELECTION MODEL IN THE CONSTRUCTION INDUSTRY

Through literature reviews and information extracted from business firms, this study collates the general contractors' selection factors of the subcontractors and the hierarchal relationship among these factors. The hierarchal relationship among different factors is acquired after revision is made by two experts. The relationship is further used as the basis for the formulation of questionnaires. The establishment process of the hierarchal relationship and the analytic results are explained as follows.

Establishment of the hierarchal structure and the nature of the attributes

Many factors were found to influence the general contractors' selection of the subcontractors. Having interviewed the experts and the managers with working experience in the construction industry for more than 10 years, the researchers summarize the information from 5 perspectives: quality control, economic perspective, technology perspective, collaboration level and progress control. These 5 perspectives can further be divided into 14 items. The relationship between each perspective and the items are shown in Figure 1.

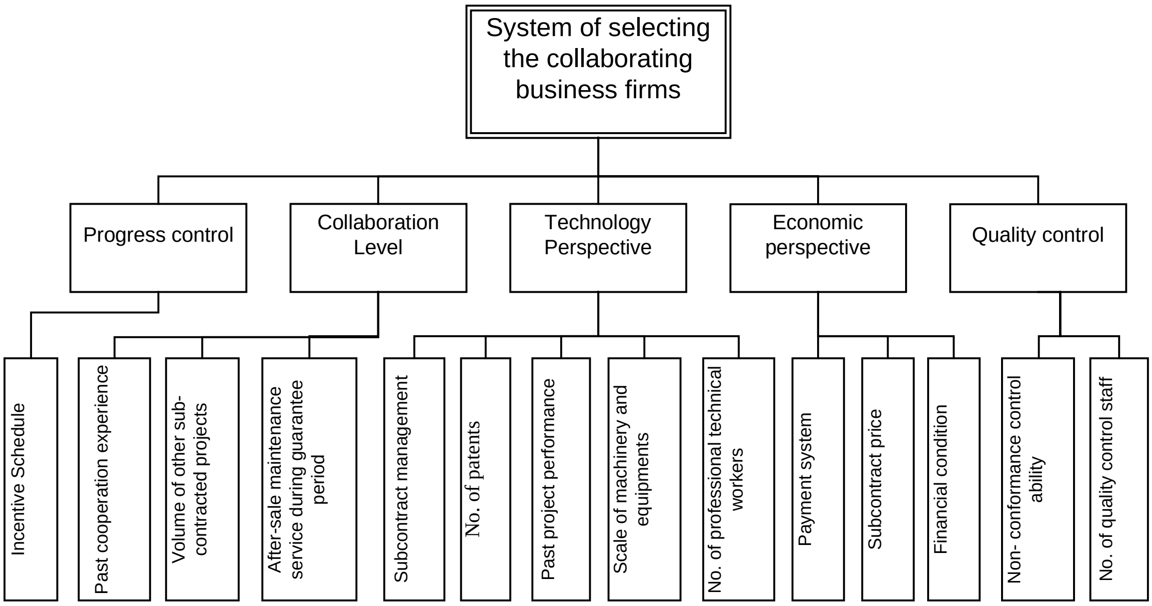


Figure 1: Structure of the selection system of subcontractors

Quality control perspective

As more attention has been placed on the engineering quality in Taiwan, general contractors have thus been receiving greater pressure of quality from the real estate owners. Therefore, during the selection of subcontractors, more and more general contractors lay particular concerns on the quality control ability. General contractors evaluate the quality control ability of a subcontractor from two aspects:(1) number of quality control staff; and (2) non-conformance control ability.

Economic and financial conditions

To both the general contractor and the subcontractors, making profit is the first priority of the purposes of operation. Therefore, both parties care much about the economic indices of their companies' operation. When a general contractor is selecting the subcontractors, there are three indices most commonly mentioned:(1) financial condition; (2) proposed prices by subcontractors; and (3) payment system.

Technology perspective

In the five evaluation perspectives, what technology perspective represents is the ability performing professional skills of a business firm. Since technology-ability of a business firm is usually associated with the technical workers and the resource allocation ability, the evaluation items of this perspective include five items:(1) number of professional technical workers; (2) scale of machinery and equipments; (3) actual project performance; (4) number of patents; and (5) number of times of subcontracting the projects.

Collaboration level

In most of the interviews, a majority of the targeted general contractors mentioned a rather obscure but important evaluation items of the subcontractors: "collaboration level". Furthermore, this study attempts to divide the collaboration level into three parts: (1) after-sale maintenance service during the guarantee period; (2) volume of other subcontracted projects; and (3) past cooperation experience.

Progress control

Progress control is a very important perspective in the project control. Its main evaluation item is the subcontractor's ability of the incentive schedule of a project. In the study, this item is assumed/found to be a positive qualitative index.

Determining the evaluation criteria weights

Since the evaluation criteria of the general contractors' selection of subcontractors have diverse levels of significance and meanings, it is not suitable to assume that each evaluation criterion is of equal importance. Many methods were employed to determine the level of significance of the effects on the project performance, such as the eigenvector method, weighted least square method, entropy method etc. (Hwang and Yoon 1981). To select the subcontractors for a general contractor is a complex and wide-ranging problem, so this problem requires the most inclusive and flexible method. The AHP developed by Saaty (1980) is a very powerful tool to assist users to carry decision making with multiple criteria and has successfully been applied to many related cases in the construction industry (McIntyre and Parfitt 1998; Fong and Choi 2000; Al-Harbi 2001; Cheung *et al*. 2001; Mahdi *et al*. 2002; Al Khalil 2002; Cheung *et al*. 2002). However, during the operation of implementing the AHP method, it is easier for evaluators to make decision on "item A is much more important than item B" than "the ratio of level of significance between item A and item B is seven". Hence, Buckley (1985) updated Saaty's AHP to the condition where the evaluators are allowed to employ fuzzy ratios in place of exact ratios to solve the problem of difficult decisions for evaluators. Therefore, in this study, we employ Buckley's method, FAHP, to fuzzify hierarchical analysis by allowing fuzzy numbers for the pairwise comparisons, and figure out the fuzzy weights of the investigated factors.

Fuzzy Analytic Hierarchy Process (FAHP)

The procedure for determining the evaluation criteria weights by FAHP can be summarized as follows:

Step 1: construct pairwise comparison matrices among all the elements/criteria in the dimensions of the hierarchy system. Assign linguistic terms to the pairwise comparisons by asking which is the more important of each two elements/criteria, such as

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ 1/\tilde{a}_{12} & 1 & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/\tilde{a}_{1n} & 1/\tilde{a}_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

where

$$\tilde{a}_{ij} = \begin{cases} \tilde{1},\tilde{3},\tilde{5},\tilde{7},\tilde{9}, & \textit{criterion i is relative } \text{importance } \textit{to criterion } j \\ 1, & i = j \\ \tilde{1}^{-1},\tilde{3}^{-1},\tilde{5}^{-1},\tilde{7}^{-1},\tilde{9}^{-1}, & \textit{criterion i is relative less } \text{importance } \textit{to criterion } j \end{cases}$$

Step 2: to use geometric mean technique to define the fuzzy geometric mean and fuzzy weights of each criterion by Buckley (1985) as follows:

$$\tilde{r}_i = (\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{in})^{1/n}, \quad \tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_n)^{-1} \quad (2)$$

where $\tilde{a}_{in}$ is fuzzy comparison value of criterion *i* to criterion *n*, thus, $\tilde{r}_i$ is geometric mean of fuzzy comparison value of criterion *i* to each criterion , $\tilde{w}_i$ is the fuzzy weight of the i^{th} criterion, can be indicated by a triangular fuzzy number, $\tilde{w}_i = (Lw_i, Mw_i, Uw_i)$. Here Lw_i, Mw_i and Uw_i stand for the lower, middle and upper values of the fuzzy weight of the i^{th} criterion.

Table 1: Membership function of linguistic scale

Fuzzy number	Linguistic scales	Scale of fuzzy number
$\tilde{1}$	Equally important (Eq)	(1,1,3)
$\tilde{3}$	Weakly important (Wk)	(1,3,5)
$\tilde{5}$	Essentially important (Es)	(3,5,7)
$\tilde{7}$	Very strongly important (Vs)	(5,7,9)
$\tilde{9}$	Absolutely important (Ab)	(7,9,9)

Note: this is synthesized the linguistic scales defined by Chiou and Tzeng (2001) and fuzzy number scale used in Mon *et al*. (1994).

Fuzzy Multiple Criteria Decision-Making (FMCDM)

Bellman and Zadeh (1970) were the first to probe into the DM problem under a fuzzy environment, and they heralded the initiation of FMCDM. This analysis method has been widely used to deal with DM problems involving multiple criteria evaluation/selection of alternatives. The practical applications reported in the literatures are: weapon system evaluating (Mon *et al*. 1994); technology transfer strategy selection in biotechnology (Chang and Chen 1994); optimization of the design process of truck components (Altrock and Krause 1994); energy supply mix decisions (Tzeng *et al*. 1994); urban transportation investment alternatives selection (Teng and Tzeng 1996); tourist risk evaluation (Tsaur *et al*. 1997); electronic marketing strategies evaluation in the information service industry (Tang *et al*. 1999); restaurant location selection (Tzeng *et al*. 2002), and performance evaluation of distribution centres in logistics (Chen 2002). These studies showed advantages in handling unquantifiable/qualitative criteria, and obtained quite reliable results. This study uses the method proposed by Bellman and Zadeh with the FMCDM theory to evaluate the subcontractors and rank the priority for them accordingly. The following will be the method and procedures of the FMCDM theory.

Alternatives measurement

The measurement of linguistic variables was applied to demonstrate the criteria performance (effect-values) by expressions such as "very good", "good", "fair", "poor" and "very poor". The evaluators were asked to conduct their subjective judgments, and then each linguistic variable can be formulated by a triangular fuzzy number within the scale range of 0–100, as shown in Figure 2. In addition, the evaluators can subjectively assign their personal range of the linguistic variable that can indicate the membership functions of the expression values of each evaluator. Take $\tilde{E}_{ij}^k$ to indicate the fuzzy performance value of evaluator *k* towards subcontractor *i* under criterion *j*, and all of the evaluation criteria will be indicated by $\tilde{E}_{ij}^k = (LE_{ij}^k, ME_{ij}^k, UE_{ij}^k)$. Since the perception of each evaluator varies according to the evaluator's experience and knowledge, and the definitions of the linguistic variables vary as well, this study uses the notion of average value to integrate the fuzzy judgment values of *m* evaluators, that is,

$$\tilde{E}_{ij} = (1/m) \otimes (\tilde{E}_{ij}^{1} \oplus \tilde{E}_{ij}^{2} \oplus \cdots \oplus \tilde{E}_{ij}^{m}) \qquad (3)$$

The sign $\otimes$ denotes fuzzy multiplication, the sign $\oplus$ denotes fuzzy addition, $\tilde{E}_{ij}$ shows the average fuzzy number of the judgment of the decision-makers, which can be displayed by a triangular fuzzy number as $\tilde{E}_{ij} = (LE_{ij}, ME_{ij}, UE_{ij})$. The end-point values LE_{ij}, ME_{ij}, and UE_{ij} can be solved by the method put forward by Buckley (1985),

$$LE_{ij} = \left(\sum_{k=1}^{m} LE_{ij}^{k}\right) \Big/ m; \quad ME_{ij} = \left(\sum_{k=1}^{m} ME_{ij}^{k}\right) \Big/ m; \quad UE_{ij} = \left(\sum_{k=1}^{m} UE_{ij}^{k}\right) \Big/ m \qquad (4)$$

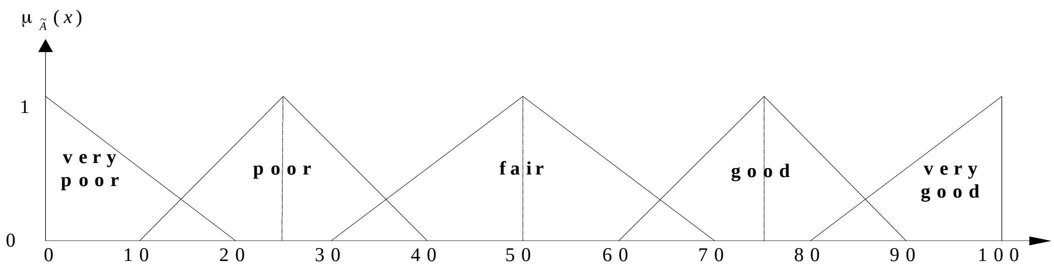


Figure 2: Example of membership function of linguistic variables for measuring the performance value of subcontractors

Fuzzy synthetic decision

According to the each criterion weight $\tilde{w}_j$ derived by FAHP, the criteria weight vector $\tilde{\boldsymbol{w}} = (\tilde{w}_1, \ldots, \tilde{w}_j, \ldots, \tilde{w}_n)^t$ can be obtained, whereas the fuzzy performance matrix $\tilde{\boldsymbol{E}}$ of each of the subcontractors can also be obtained from the fuzzy performance value of each subcontractor under n criteria, that is, $\tilde{\boldsymbol{E}} = (\tilde{E}_{ij})$. From the criteria weight vector $\tilde{\boldsymbol{w}}$ and fuzzy performance matrix $\tilde{\boldsymbol{E}}$, the final fuzzy synthetic decision can be conducted, and the derived result will be the fuzzy synthetic decision matrix $\tilde{\boldsymbol{R}}$, that is,

$$\tilde{\boldsymbol{R}} = \tilde{\boldsymbol{E}} \circ \tilde{\boldsymbol{w}} \qquad (5)$$

The sign "o" indicates the calculation of the fuzzy numbers, including fuzzy addition and fuzzy multiplication. Since the calculation of fuzzy multiplication is rather complex, it is usually denoted by the approximate multiplied result of the fuzzy multiplication, and the approximate fuzzy number $\tilde{R}_i$, of the fuzzy synthetic decision of each alternative can be shown as $\tilde{R}_i = (LR_i, MR_i, UR_i)$, where LR_i, MR_i and UR_i are the lower, middle and upper synthetic performance values of the alternative i, that is:

$$LR_i = \sum_{j=1}^{n} LE_{ij} \times Lw_j; \; MR_i = \sum_{j=1}^{n} ME_{ij} \times Mw_j; \; UR_i = \sum_{j=1}^{n} UE_{ij} \times Uw_j \qquad (6)$$

Ranking the fuzzy number

The result of the fuzzy synthetic decision reached by each subcontractor is a fuzzy number. Therefore, it is necessary that a non-fuzzy ranking method for fuzzy numbers be employed for comparison of each subcontractor. In other words, the procedure of defuzzification is to locate the Best Non-fuzzy Performance value (BNP). Methods of such defuzzified fuzzy ranking generally include mean of maximal (MOM), centre of area (COA), and α-cut (Teng and Tzeng 1996). To utilize the COA method to find out the BNP is a simple and practical method, and there is no need to bring in the preferences of any evaluators, so it is used in this study. The *BNP* value of the fuzzy number $\tilde{R}_i$ can be found by the following equation:

$$BNP_i = [(UR_i - LR_i) + (MR_i - LR_i)]/3 + LR_i, \quad \forall\, i \tag{7}$$

According to the value of the derived *BNP* for each of the subcontractors, the ranking of the subcontractors can then proceed.

CASE STUDY ANALYSIS

Background of the case

A case study was conducted to select a subcontractor for a traditional painting project of a newly constructed office building. The total amount of the entire construction project is $360 million, and the painting project is about $24 million. There are five business firms being considered by the general contractor.

The weights of selection criteria

Since the selection of professional subcontractors involves many professional assessments and has significant effects on overall performance of a project to the general contractors, this study conducted a questionnaire survey on the worksite supervisors and project managers who have practical experience and professional decision-making authority, as well as the professional person-in-charge of a company for acquiring their opinions on the selection of qualified subcontractors. From the survey, the three decision-makers' weights, shown in Table 2, towards the five perspectives and fourteen selection criteria were developed. The results and analysis of the weights of different selection criteria are presented as follows:

Comparison of weights on the five perspectives

From the analysis on the ranking of the weights (as the level of significance) of five perspectives during a general contractor's selection of the subcontractor, i.e. technology, quality, collaboration level, progress and economical level, it was found that the most important one should be the technological execution ability, which is followed by quality control, but the difference of their weights is not too significant (0.302 and 0.295). It implies that the general contractors highest concern is whether the project item subcontracted to the subcontractor can be completed corresponding to the specified quality standards to avoid the penalty charged by the project owner. According to the results of weights analysis, the more surprising result is that the weight of economic conditions is rather low (0.044). This result seems to be tremendously different from the instinct perception that general contractors take the lowest price as the main subcontracting means.

Comparison of weights on the selection criteria

Regarding the quality control perspective, the concerns that the investigated general contractor laid on the non-conformance control ability are far more than the number of quality control staff. It implies that the substantial quality control result is more appropriate than the number of quality control staff. For the economic perspective, the financial condition and the payment system are not at all the concerned items to the general contractor in the case study since their proportions are below 1% (weights being 0.006 and 0.009 respectively). As to the technology perspective, past project performance (0.161) is more significant compared to other items. It represents the past experience accumulated by the subcontractor, which of course gains a certain degree of attention from a general contractor. Besides, although the general contractor puts less concerns on the subcontract management than the past project performance by

10% (0.06), it is ranked as the second significant item on the perspective of technology execution ability. It refers that the general contractor puts more concerns on the problems of subcontract managements than the number of technical workers and the scales of machinery. For the perspectives of collaboration level and progress control, the higher weights of past cooperation experience and promptness in completion (0.14 and 0.156 respectively) also show that the interviewed general contractors are more concerned on the project management process and the execution results. It should also be the main reason for the general contractor to bear the responsibility for the ultimate result of the overall project performance.

Table 2: Table of average weights of the evaluation perspectives and criteria

Evaluation perspectives	Weights	Evaluation criteria	Weights
Quality control	0.295	No. of quality control staff (C1)	0.052
		Non-conformance control ability (C2)	0.243
Economic	0.044	Financial condition (C3)	0.006
		Subcontract price (C4)	0.029
		Payment system (C5)	0.009
Technology	0.302	No. of professional technical workers (C6)	0.031
		Scale of machinery & equipments (C7)	0.017
		Past project performance (C8)	0.161
		No. of patents (C9)	0.033
		Subcontract management (C10)	0.060
Collaboration level	0.203	After-sale maintenance service during guarantee period (C11)	0.037
		Volume of other subcontracted projects (C12)	0.027
		Past cooperation experience (C13)	0.140
Progress control	0.156	Promptness in completion (C14)	0.156

Evaluation results of each subcontractor to be selected

This paper uses the method of average value to integrate different decision-makers' fuzzy judgment value towards the same selection criterion. It also refers to the employment of fuzzy addition and fuzzy multiplication to figure out the average fuzzy values of the performance values given by each decision-maker to each evaluation item of each investigated business firm (Table 3).

From the weights acquired from the calculation by FAHP (Table 2) and the performance value of each evaluation criterion given by the decision-maker (Table 3), it can be induced that the final fuzzy synthetic decision of each investigated subcontractor is R_i. Based on the fuzzy decision result, and by using the COA, the study explores the best non-fuzzy performance value (BNP_i), which is taken as the ranking of the five investigated business firms. The ranking results are displayed in Table 3.

Table 3: Average fuzzy performance values and ranking results of each subcontractor

Evaluation Criterion	Business Firm 1	Business Firm 2	Business Firm 3	Business Firm 4	Business Firm 5
C1	(50.0,68.3,76.7)	(50.0,68.3,76.7)	(68.3,81.7,90.0)	(65.0,80.0,90.0)	(55.0,70.0,80.0)
C2	(48.3,63.3,73.3)	(63.3,76.7,86.7)	(81.7,88.3,96.7)	(65.0,80.0,90.0)	(81.7,88.3,96.7)
C3	(58.3,75.0,83.3)	(63.3,76.7,86.7)	(58.3,75.0,83.3)	(56.7,73.3,83.3)	(55.0,70.0,80.0)
C4	(43.3,61.7,70.0)	(75.0,83.3,90.0)	(50.0,68.3,76.7)	(28.3,38.3,50.0)	(36.7,51.7,63.3)
C5	(43.3,61.7,70.0)	(48.3,63.3,73.3)	(48.3,63.3,73.3)	(48.3,63.3,73.3)	(48.3,63.3,73.3)
C6	(36.7,51.7,63.3)	(56.7,70.0,80.0)	(80.0,85.0,93.3)	(63.3,78.3,86.7)	(51.7,63.3,76.7)
C7	(43.3,61.7,70.0)	(70.0,78.3,86.7)	(50.0,68.3,76.7)	(40.0,58.3,66.7)	(61.7,71.7,80.0)
C8	(48.3,63.3,73.3)	(55.0,70.0,80.0)	(80.0,85.0,93.3)	(33.3,46.7,60.0)	(55.0,70.0,80.0)
C9	(33.3,46.7,56.7)	(33.3,46.7,56.7)	(33.3,46.7,56.7)	(33.3,46.7,56.7)	(33.3,46.7,56.7)
C10	(26.7,41.7,53.3)	(61.7,71.7,80.0)	(66.7,73.3,83.3)	(68.3,76.7,86.7)	(33.3,46.7,60.0)
C11	(76.7,83.3,93.3)	(76.7,83.3,93.3)	(70.0,85.0,93.3)	(76.7,83.3,93.3)	(76.7,83.3,93.3)
C12	(63.3,76.7,86.7)	(63.3,76.7,86.7)	(80.0,85.0,93.3)	(70.0,85.0,93.3)	(70.0,85.0,93.3)
C13	(43.3,56.7,70.0)	(50.0,66.7,76.7)	(56.7,73.3,83.3)	(56.7,73.3,83.3)	(56.7,73.3,83.3)
C14	(70.0,78.3,86.7)	(70.0,78.3,86.7)	(75.0,80.0,90.0)	(76.7,83.3,93.3)	(76.7,83.3,93.3)
R_i	(50.23,63.93,74.11)	(60.05,72.95,82.39)	(71.33,80.32,89.33)	(58.60,71.44,81.91)	(63.76,75.03,84.91)
BNP_i	62.76	71.79	80.33	70.65	74.57
Ranking	5	3	1	4	2

Business firm 3 > Business firm 5 > Business firm 2 > Business firm 4 > Business firm 1

CONCLUSIONS AND SUGGESTIONS

Since most general contractors encounter the problems of unclear standards and insufficient information, it is difficult for them to figure out the qualified subcontractors for their projects. To solve this problem, the study underwent literature reviews, analysis on the accumulated information, interviews with experts, application of FAHP and analysis of cases, and finally developed a set of rather objective standards of selecting subcontractors. Meanwhile, the following conclusions and suggestions are made:

1. There is a clear hierarchal relationship among the factors of the general contractors' selection of subcontractors. It is really workable to implement the fuzzy analytic hierarchy process (FAHP) to establish the selection standards, and employ the fuzzy multiple criteria decision-making (FMCDM) to quantify the selection item that could not be measured in quantitative. This paper provides a workable research direction.

2. The study develops the weights of the five perspectives for the general contractor's selection of subcontractors. The ranking of these five perspectives are: (1) technology execution ability of subcontractor, being 30.2%; (2) quality control ability, being 29.5%; (3) collaboration level, being 20.3%; (4) progress control ability, being 15.6%; and (5) economic and financial conditions, being 4.4%.

3. The study is a preliminary study. As limited by time, it can only adopt the opinions of three decision-makers, so the representative of the acquired results still needs to be strengthened. Besides, the study needs subsequent expansion of the selection of samples and the strengthening of the verification of actual examples.

REFERENCES

Al-Harbi, K M (2001) Application of the AHP in project management. *International Journal of Project Management*, **19**(1), 19–27.

Al Khalil, M I (2002) Selecting the appropriate project delivery method using AHP. *International Journal of Project Management*, **20**(6), 469–74.

Altrock, C V and Krause, B (1994) Multi-criteria decision-making in German automotive industry using fuzzy logic. *Fuzzy Sets and Systems*, **63**(3), 375–80.

Bellman, R E and Zadeh, L A (1970) Decision-Making in a Fuzzy Environment. *Management Science*, **17**(4), 141–64.

Buckley, J J (1985) Ranking Alternatives Using Fuzzy Numbers. *Fuzzy Sets and Systems,* **15**(1), 21–31.

Chang, P L and Chen, Y C (1994) A fuzzy multi-criteria decision making method for technology transfer strategy selection in biotechnology. *Fuzzy Sets and Systems*, **63**(1), 131–9.

Chen, Y C (2002) An application of fuzzy set theory to external performance evaluation of distribution centers in logistics. *Soft Computing*, **6**(1), 64–70.

Cheung, F K T, Kuen, J L F and Skitmore, M (2002) Multi-criteria evaluation model for the selection of architecture consultants. *Construction Management and Economics*, **20**(7), 569–80.

Cheung, S O, Lam, T I, Leung, M Y and Wan, Y W (2001) An analytical hierarchy process based procurement selection method. *Construction Management and Economics*, **19**(1), 427–37.

Chiou, H K and Tzeng, G H (2001) Fuzzy hierarchical evaluation with grey relation model of green engineering for industry. *International Journal of Fuzzy System*, **3**(3), 466–75.

Fong, S W and Choi, S K Y (2000) Final contractor selection using the analytical hierarchy process. *Construction Management and Economics*, **18**(5), 547–57.

Mahdi, I M, Riley, M J, Fereig, S M and Alex, A P(2002) A multi-criteria approach to contractor selection. *Engineering, Construction and Architectural Management*, **9**(1), 29–37.

McIntyre, C and Parfitt, M K (1998) Decision Support System For Residential Land Development Site Selection Process. *Journal of Architectural Engineering*, ASCE, **4**(4), 125–31.

Mon, D L, Cheng, C H and Lin, J C (1994) Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight. *Fuzzy Sets and Systems*, **62**(2), 127–34.

Saaty, T L (1977) A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, **15**(2), 234–81.

Saaty, T L (1980) *The Analytic Hierarchy Process*. New York: McGraw-Hill.

Tang, M T, Tzeng, G H and Wang, S W (1999) A Hierarchy Fuzzy MCDM Method for Studying Electronic Marketing Strategies in the Information Service Industry. *Journal of International Information Management*, **8**(1), 1–22.

Teng, J Y and Tzeng, G H (1996) Fuzzy Multicriteria Ranking of Urban Transportation Investment Alternatives. *Transportation Planning and Technology*, **20**(1), 15–31.

Tsaur, S H, Tzeng, G H and Wang, G C (1997) The Application of AHP and Fuzzy MCDM on the Evaluation Study of Tourist Risk. *Annals of Tourism Research*, **24**(4), 796–812.

Tzeng, G H, Shiah, T A and Teng, J Y(1994) A Multi-objective Decision Making Approach to Energy Supply Mix Decisions in Taiwan. *Energy Sources*, **16**(3), 301–16.

Zadeh, L A (1965) Fuzzy set. *Information and Control*, **8**(2), 338–53.

Zadeh, L A (1975, 1976) The concept of a linguistic variable and its application to approximate reasoning. *Information Sciences*, **8**(1), 199–249; **8**(2), 301–57; **9**(3), 43–80.

AN OPTION-BASED DYNAMIC OPTIMIZATION MODEL TO EVALUATE ADR INVESTMENTS IN AEC CONSTRUCTION PROJECTS

Carol Menassa[1] and Feniosky Peña Mora

Civil and Environmental Engineering Department, University of Illinois at Urbana-Champaign, 205 North Mathews Avenue, Urbana, IL 61801, USA

Managing claims and mitigating their adverse impact on a construction project is a major concern for AEC industry participants. Alternative dispute resolution (ADR) techniques can be implemented to achieve reasonable settlement of claims, and avoid their escalation to disputes that require protracted litigation for final determination of merit. These ADR techniques require allocation of resources internally within the corporation and externally in the form of third party assisted ADR. Managerial decisions regarding the size, timing and required expenses for these resources need to be economically justified. A cost–benefit analysis of ADR investments is developed using dynamic optimization, which allows for the division of ADR investments into two parts: immediate and subsequent ADR investment decisions made during the construction phase of the project. In the model, having the option to invest in a given ADR process to resolve claims in a project is seen as being analogous to having 'real options' on capital investment projects. The simulation of the model results in an ADR investment profile that depicts the ADR expenditure trend throughout the project life cycle based on the owner's perception of the uncertainty associated with the occurrence of the claim and the effectiveness of the chosen ADR process.

Keywords: claims, cost–benefit analysis, real options investment in alternative dispute resolution, risk and uncertainty.

INTRODUCTION

The construction industry in the US spends an estimated amount of $13–26 billion on change orders and claims (Hanna and Gunduz 2004) per year. These figures are relatively high when compared to the total share of the construction industry to the US gross domestic product (GDP) which reached 1.14 trillion or 9% of the GDP in 2005 (AGC 2006). According to Associated General Contractors (AGC) CEO Stephen Sandherr, 'every dollar added to construction adds $2 to the GDP' (AGC 2003). Thus, every dollar spent on change orders and claims will have an impact on the construction industry's role as a major contributor to the economy.

Change orders and claims occur on a regular basis when the contractor believes that he is entitled to additional compensation and/or an extension of time beyond what was originally agreed upon in the contract documents (Fenn *et al*. 1998; Adrian 1988). When the owner of the construction project determines that the claim is baseless and refuses to compensate the contractor either partially or in full, the claim escalates to a dispute. At this phase the owner and the contractor, either willingly or because they are forced to by the contract, engage in an alternative dispute resolution (ADR) process in

[1] menassa2@uiuc.edu

an attempt to resolve the claims at the project level, and preserve an amicable working environment to ensure that the project is completed as initially planned in terms of schedule, budget and quality.

In this context, alternative dispute resolution is a catchall term that describes a number of methods used to resolve disputes out of court, including negotiation, standing neutral advisors and arbitration (Caltrans 2000; USACE 1989). A common denominator of all ADR methods is that they are faster, less formalistic and often less adversarial than a court trial. However, most of these techniques require the allocation of resources by all parties involved in the project to analyse claims and determine their validity, or with external input when claims can only be resolved through third party assistance. Given that most construction projects operate on tight budgets, managerial decisions regarding the size, organization, timing and amount of expenditure required to implement a given ADR in the project need to be economically justified. In other words, every dollar invested in a given ADR process needs to be outweighed by the perceived benefits for it to be worthwhile. These perceived benefits include settling the claim at lower values than what was originally claimed by the contractor. When the difference between the original amount claimed and the actual amount of settlement (what was actually paid to the contractor) is positive, and exceeds the amount invested in the ADR, then the investment is worthwhile.

However, the severity, time of occurrence and amount of change orders and claims in construction projects are directly related to certain project characteristics such as the type of project and the contractual arrangement between the participants, which makes it hard to predict the amount and time of occurrence of these claims during the planning phase of the project when decisions regarding the type and amount of investment in ADR need to be made. Added to this, there is the difficulty in estimating the effectiveness of the ADR in resolving these claims. The difficulty in estimating the expected cash flows from a given ADR investment implies that the application of the traditional net present value technique to value these investments will not reflect the actual value of these investments nor provide the owner with the flexibility of timing these investments based on how claims escalate during construction.

In order to overcome the project and ADR uncertainties, and estimate the cost–benefit trade-offs of any ADR investment decision, the owner of a construction project needs a decision-making tool that provides flexibility as to how much needs to be expended and the optimal timing of these investments. In order to develop such a framework, this research investigated the possibility of using option valuation techniques to value ADR investment decisions in construction projects. In particular, the dynamic optimization technique presented by Majd and Pindyck (1987) is adapted to model ADR investments, and evaluate optimal investment decisions related to the timing and the amount of expenditure. The model developed illustrates that when parameters of valuation are optimally chosen then such a framework can assist in guiding ADR investment decisions throughout the project construction phase by providing the owner with an ADR investment profile that spans the construction phase of the project.

CHARACTERISTICS OF ADR INVESTMENTS IN CONSTRUCTION PROJECTS

Change orders and claims occur on a regular basis in most architecture, engineering and construction projects. They are usually initiated by the contractor due to delays on the part of the owner (for example, in providing the contract drawings); performing work not within the scope of the original tender documents; performing work which, though included in the contract documents, is more difficult than that described in the contract documents or is undertaken under different circumstances (for example, the contractor expected to have a clear site but arrived to find a number of other trade contractors working on the site); the owner requesting additional work or deleting work from the work described in the original tender documents (Adrian 1988). In each of these and other circumstances, the contractor believes that his claim has merit and entitles him to additional payment and/or an extension of time. When the owner of the construction project determines that the claim is baseless and refuses to compensate the contractor either partially or in full, the claim escalates to a dispute. At this point the owner and the contractor, either willingly or because they are forced to by the contract, engage in an ADR process in an attempt to resolve claims at the project level, and preserve an amicable working environment to ensure that the project is completed as initially planned in terms of schedule, budget and quality. A number of methods that can be specifically adapted to the different phases of a construction project are shown in Figure 1 (Peña Mora *et al*. 2003; AGC 2000). The owner of a construction project might choose to implement different ADR processes to address the different levels of claim severity as part of a dispute resolution framework. For example, California Department of Transportation (Caltrans) dispute resolution process involves partnering on construction projects with bid estimates exceeding $25 million. This is coupled with negotiation at the initial stages of the claim followed by dispute review board hearings (standing neutral) if the project has not been completed, and arbitration if the contractor files the claim after the project has been completed and turned over to Caltrans (Caltrans 2000).

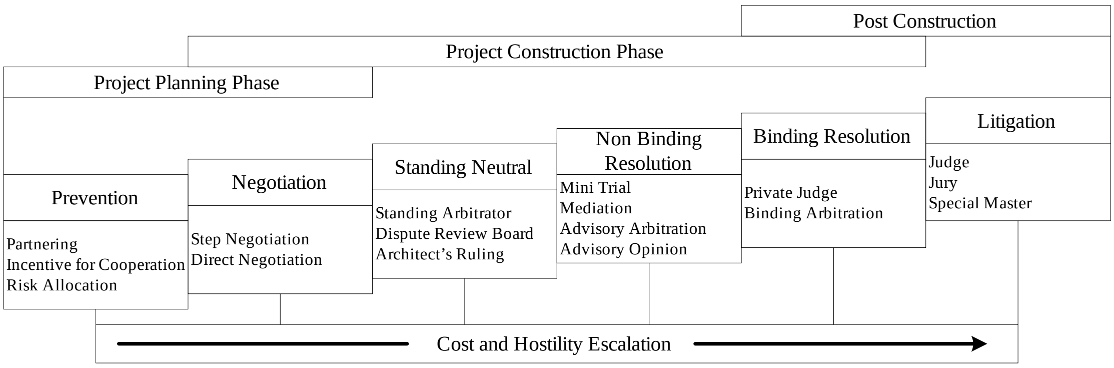


Figure 1: Steps in the construction dispute resolution (adapted from Peña Mora *et al*. 2003 and AGC 2000)

As is the case in any investment opportunity, the perceived benefits (e.g. estimated savings in the project due to claim avoidance and mitigation) from any ADR implementation must outweigh its costs for the investment to be worthwhile. These perceived benefits can be calculated as the difference between the original amount of the claim as indicated in the contractor's notice of claim and the actual amount of settlement achieved after ADR implementation. For example, suppose the contractor files a claim whose amount is $100 000 due to unforeseen site conditions that required the contractor to change the type of foundation for a building project, and the owner rejects this claim because of a contract clause requiring the contractor to inspect the site to determine its condition prior to initiation of construction. If the owner and contractor reach an impasse and cannot resolve this claim through negotiation, they might decide to attempt to resolve this claim by seeking the advice of a third party neutral arbitrator. This arbitrator will review the position of each party, and try to mediate a settlement based on the entitlement of each party. If this arbitrator determines that the contractor is entitled to $70 000 instead of the originally claimed $100 000, then the net saving to the project budget from implementing this ADR is $30 000. Now if the arbitrator's fees exceed this amount, then the investment in the ADR needs to be rejected. However, if the arbitrator's fees are lower than $30 000, then it might be optimal to consider investing in this ADR. Valuation tools like the net present value can be used to perform this analysis when explicit assumptions regarding the expected cash flows (cost of ADR and perceived savings in project) can be determined with certainty during the planning phase of the project. More specifically, in order to properly evaluate ADR investments using the net present value technique the cash flows related to the amount claimed, amount settled and ADR cost need to be estimated with certainty for the analysis to yield acceptable results.

However, ADR investment decisions are often made within the context of three main characteristics, namely: irreversibility, uncertainty and timing. These characteristics are typical of any capital investment project (Dixit and Pindyck 1994). Once the means of ADR is chosen and implementation initiated at the start of construction, any costs incurred become sunk costs that cannot be recovered by the owner in case the chosen method of ADR proves ineffective in addressing claims occurring in the project. Also, the occurrence of conflicts and claims can only be determined with certainty once the project is underway, which creates difficulty in estimating the expected cash flows from an ADR implementation. The cash flows from any ADR investment in a construction project, and the related sources of uncertainty, are shown in Figure 2.

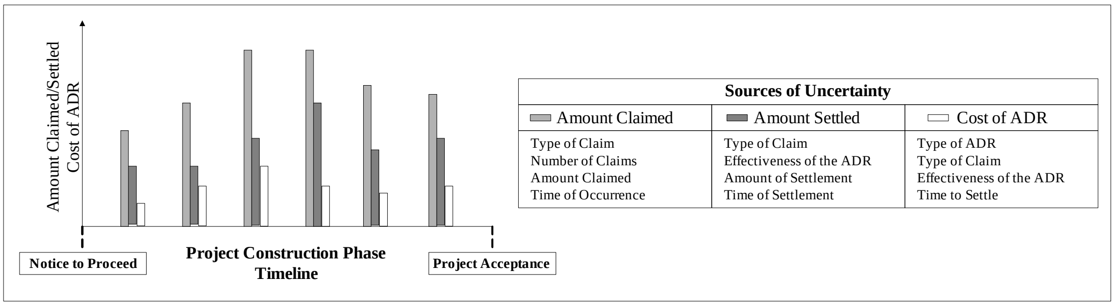


Figure 2: Sources of uncertainty for ADR investment cash flows

Finally, the project owner, who does not know whether a given ADR will be needed to resolve claims that might arise in the project due to certain project indicators, will consider a full investment in the ADR at the beginning of the project a risky undertaking. The variation in the investment decision based on the perceived level of uncertainty is shown in Figure 3.

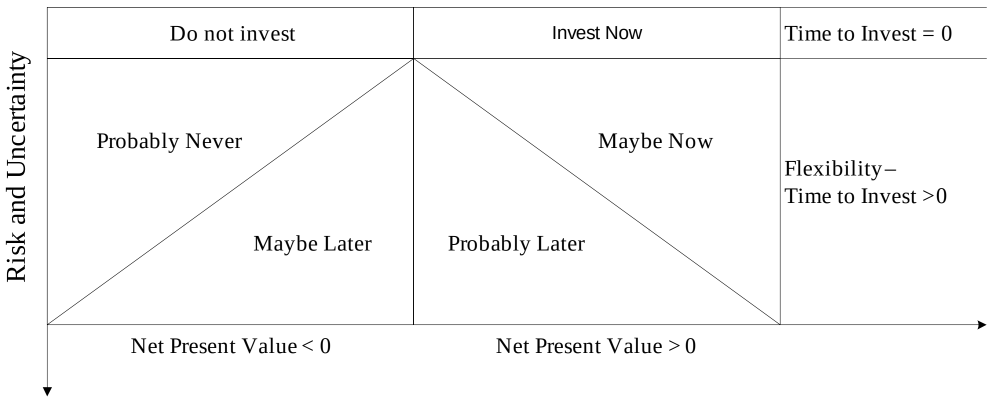


Figure 3: ADR investment space (adapted from Luehrman 1998)

FINANCIAL AND REAL OPTIONS

Options on traded assets like stocks, foreign currencies and commodities give the holder the right to buy (call options) or sell (put options) these assets at a fixed price (referred to as the exercise price) on or before expiration date (Hull 2000). European options can only be exercised on the expiration date, while American options can be exercised any time before expiration. The owner of the option has the right but not the obligation to pay the total sunk cost or exercise price in return for the stock. Options offer the investor the flexibility to postpone investment decisions until information about future market conditions become available; thus, buying/selling occurs only if market conditions are favourable and positive payoffs are realized. This 'caps' the losses down to zero (no negative payoffs) when market conditions are not favourable (Fichman and Tiwana 2005).

The modern theory of option pricing dates to 1973 when Black and Scholes presented a formula for valuing call options as a function of the price of the underlying common stock *S*, the exercise price *X*, uncertainty σ, risk free interest rate *r*, and time until expiration *T*. The basic assumption underlying this solution is that the change in the stock price follows a geometric Brownian motion, a special case of the stochastic generalized Wiener process, of the form $dS/S = \mu dt + \sigma dz$ (Wilmott *et al*. 2005; Hull 1999; Trigeorgis 1996; Dixit and Pindyck 1994). The parameter μ represents the instantaneous growth rate in the price of the stock over time, σ the associated proportional standard deviation parameter, and *dz* is the increment of the standard Wiener process that is normally distributed with a mean of 0 and a variance that increases linearly with the time interval *dt*. The main idea behind this assumption is that the stock price change has a deterministic component μdt that depends on the average rate of return expected by investors from the given stock, and a stochastic component σdz that depends on the volatility or the standard deviation of the returns associated with the market conditions.

An important application of this option pricing theory comes in the form of real options, or the ability to evaluate investments in capital (that is, non-financial) projects by drawing analogies from financial market options (Boute 2004; Trigeorgis 1993). Real options give the capital investor the flexibility to defer, expand, stage or abandon the investment at any time during the project life cycle in response to changes in the future circumstances of the project. This flexibility adds more value to the investment opportunity because the investor has the opportunity to strategically make expenditures in the project depending on the market conditions (Boute 2004; Trigeorgis 1996; Nichols 1994; Sick 1989). For example, a planned investment to acquire a cement factory is analogous to a call option on the stock with the underlying asset being the price of the cement or the expected future demand for the cement in the market. If the same investor realizes that the demand for cement will drop he might decide to dispose of the project for a salvage value, which is again analogous to exercising a put option (Fichman and Tiwana 2005; Luehrman 1995).

REAL OPTIONS WHEN THERE IS 'TIME TO BUILD'

In 1987, Majd and Pindyck presented a model to evaluate investments in a factory construction project where there is 'time to build'. Time to build refers to the case when investment decisions can be made sequentially In the factory example, Majd and Pindyck (1987) present a model that provides the owner of the factory with the flexibility to adjust the rate at which construction proceeds, and in this case capital expenditures, based on the arrival of new information. This model assumes that construction (investment) can be stopped and restarted at no extra cost. The basic assumption in the model is that the owner of the factory has the right but not the obligation to pay the total construction cost in return for the completed project. As in the case of stocks, the value of the factory V is assumed to follow the standard Weiner process $dV = \alpha V dt + \sigma V dz$ where α is the expected growth rate, and σ is the uncertainty associated with the value of the completed project. At any given time during the construction period, the total remaining construction cost K ($K \leq K_0$) is assumed to be spent optimally over the construction period at a predetermined maximum rate k per unit of time. This expenditure occurs only if the value of the completed project V at that given instance of time is greater than the optimal investment value $V^*(K)$ which depends on the initial value of the investment K_0, the risk free interest rate r, the opportunity cost of capital δ, and the uncertainty in the value of the complete project σ. Thus, $V^*(K)$ is determined to be as follows:

$$V^* = \frac{\beta}{\beta - 1} K_0 \tag{1}$$

where:

$$\beta = \frac{1}{2} + \frac{(r-\delta)}{\sigma^2} + \left[\left(\frac{(r-\delta)}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2} \right]^{1/2} \tag{2}$$

This implies that the total remaining construction cost K at any time t varies as follows:

$$dK = -kdt \text{ when } V^*(K) \geq V \tag{3}$$

$$\text{and } dK = 0 \text{ otherwise} \tag{4}$$

Espinoza and Luccioni (2005) presented an approximate solution to this investment problem based on the closed form solution for perpetual American call options proposed by Samuelson (1965). If r is the risk free discount rate; $\delta = \mu - \alpha$ $(\mu > \alpha)$ is the opportunity cost; μ is the market risk adjusted expected rate of return from owning the project, then:

$$K_0 = (1 - e^{-rT})\, k/r \tag{5}$$

where K_0 is the present value of the remaining investment cost if this investment is assumed to be made continuously over the time period $T=K/k$ (time until project is completed) at a constant rate k.

The value of the investment $C(V)$ which represents the net payoffs from investing at any given time is given as:

$$C(V) = V_0 - K_0 \text{ when } V \geq V^*(K) \tag{6}$$

$$\text{and } C(V) = \frac{V^* - K_0}{(V^*)^\beta} V_0^\beta \text{ otherwise} \tag{7}$$

where V_0 is the present value of the completed project that is expected to grow at a rate α and can be estimated by discounting at the discount rate μ as follows:

$$V_0 = Ve^{(\alpha-\mu)T} = Ve^{-\delta T} \tag{8}$$

The results of this proposed approximation are successfully compared to the results obtained using the numerical analysis technique proposed by Majd and Pindyck (1987).

ADR INVESTMENTS AS REAL OPTIONS

This research focuses on analysing ADR investments in construction projects as real options. Holding an option to invest in a given ADR at the beginning of the project without committing all the resources gives the project owner the flexibility to 'call' on a specific ADR depending on the type of claims occurring in the project. For example, an owner might retain the services of a mediator during the project planning phase, and ask him to intervene only when a conflict escalates rapidly to a claim that requires third party intervention for resolution. At the same time, the owner has the flexibility to 'put' on or discard a specific ADR, and lose the initial investment if this ADR proves to be ineffective in handling the claims occurring in the project. For example, an owner might decide to forgo the services of a standing arbitrator with strong legal background if the claims filed by the contractor are related to design and construction issues. This is because even though the contract governs the relationship between the owner and the contractor, it might be necessary to resolve claims due to design and construction problems through a construction-experienced, neutral third party.

Based on the above discussion, it becomes evident that there are a lot of uncertainties surrounding the ADR investment that need to be taken into account by the owner prior to making any decision regarding which type of ADR to implement and the optimal timing of any ADR investment expenditure. That is why proper evaluation of cost–benefit trade-offs of ADR investments necessitates categorizing and understanding the sources of ADR investment risks to be able to make guided investment decisions. Two main sources of ADR investment risks have been identified by this research, namely: project-specific and ADR-specific risks that are summarized in Table 1 below.

Table 1: Sources of ADR investment risks

Project-specific risks	ADR-specific risks
1. Key project characteristics	1. Effectiveness of ADR
2. Type of claim	2. Demand for the ADR
3. Number of claims	3. Total cost of the ADR implementation
4. Time of occurrence of the claim	4. Time to settle
5. Amount claimed	5. Amount settled per each claim

Project specific risks refer to uncertainties inherent in the construction project itself. These uncertainties are directly related to the key project characteristics which include both project organizational issues like structure, process and people, as well as internal and external uncertainties (Peña Mora *et al*. 2003). For example a design-build (structure) highway project may have proper information-sharing and communication channels put in place but experiences delays (process) due to unrealistic expectations on the part of the owner and negligence on part of the contractor (people). This same project might also experience design errors and construction challenges (internal uncertainty), as well as social, environmental and political risks (external uncertainty) depending on the location where it is to be constructed. Once construction is initiated, these project characteristics have a direct effect on the types of claim (for example differing site conditions claim, design errors, material shortage, etc.), the time of occurrence of the claim (for example during the early phases, middle or last stages of construction or even after the project is turned over to the owner), and finally the amount of the claim in terms of time and money which will have a direct impact on the project schedule and budget, respectively. On the other hand, the ADR-specific risks are related to the ADR chosen and its effectiveness in addressing the claims in the project in terms of minimizing the amount claimed and time to settlement, and maximizing the expected cost savings for a given claim (difference between amount claimed and amount settled). These cost savings must outweigh the required ADR expenditure for the investment to be worthwhile.

Thus, the value of the option and decision to invest in ADR depend on several parameters, including the expected direct cost of the investment in the ADR, the initial value of the anticipated cost savings in the project, the magnitude of the up and down moves in these cost savings during the project construction phase, and the probability that these cost savings will increase/decrease in the coming periods. Also, the perception of risk is more pronounced owing the fact that, depending on the type of ADR chosen, resolution of the claims and disputes takes time during which the value of the cost savings in the project may change significantly because delaying resolution of a given claim may impact on other activities in the project and give rise to additional claims. The adoption of an ADR technique in the project is often voluntary and the time of its implementation does not follow a preset schedule but rather depends on the time of claim occurrence in the project. That is why the implementation of the ADR technique in the project can be viewed as a perpetual American call option, where the owner has the right but not the obligation to pay the total sunk cost of the ADR in return for the estimated cost savings in the project.

ADR INVESTMENT MODEL

A model to determine the optimal time to invest a certain amount *I* in ADR in return for an expected savings in the project *S* is developed using system dynamics. In this model the expected amount of the cost savings in the project *S* is analogous to the gross project value *V* for the factory project analysed by Majd and Pindyck (1987) as presented in a previous section. If the expected amount of savings due to a given ADR implementation up till time *t* during the construction phase of the project is denoted by *S(t),* then in a small time interval *dt*, this expected amount saved changes from *S(t)* to $S(t+dt) = S(t) + dS$. The formula for the change in the cumulative amount claimed is taken to be similar to the generalized Wiener process assumed for the change in gross project value, $\frac{dV}{V}$, in capital investment projects. The rate of change in the cumulative amount saved, $\frac{dS}{S}$, is therefore broken down into two main parts. One is predictable, deterministic and anticipated change similar to change in the value of a certain amount of money invested in a bank account at the risk free rate. It gives a contribution of:

$$\frac{dS_1}{S} = \mu dt \tag{9}$$

where μ = average rate of growth of the cumulative amount saved.

In this model μ is assumed to be a constant that depends on the project organization issues (structure, people and process). This implies that each type of project has a unique μ.

The second contribution to the rate of change in the cumulative amount saved, $\frac{dS}{S}$, is the random change in response to the internal and external uncertainties associated with the project. This contribution is represented by:

$$\frac{dS_2}{S} = \sigma dz \tag{10}$$

where:

σ = standard deviation (volatility) of the change in the cumulative amount S;

dz = Wiener process with the following properties: *dz* is a random variable drawn from a normal distribution, the mean of *dz* is zero, and the variance of *dz* is *dt.*

Adding together both the deterministic (Equation 9) and random contributions (Equation 10) to the change in the cumulative amount saved, we obtain the following stochastic differential equation:

$$\frac{dS}{S} = \frac{dS_1}{S} + \frac{dS_2}{S} = \mu dt + \sigma dz \tag{11}$$

The decision rules affecting the level of ADR investment at any given time during the project life cycle incorporate both the project-specific and ADR-specific risks. To develop the ADR investment model, decision rules that determine the behaviour of the system and how the investment decision changes with time due to additional information obtained about the claim situation in the project were first determined. These rules compel the owner of the construction project to either invest or forgo/defer investment in a given ADR. The decision rules used in the model correspond to the factory project decision rules stipulated in Equations 3 to 5 above. The model assumes that at a given time *t*, the current value of the cost savings *S* in the project is known. This value is unknown for subsequent periods of time; however, it is assumed to evolve according to the standard Weiner process; refer to Equations 9 to 11 above. This assumption will be further validated in the ongoing research. In this model, ADR investment expenditure is assumed to have two main characteristics:

1. Any investment expenditure is irreversible. This means that any ADR costs incurred in the project are sunk costs that cannot be recovered in case ADR fails to achieve the desired results in terms of effectively resolving the claims and realizing the perceived cost savings.
2. The ADR investment can be delayed until more information about the project claim conditions becomes available to the owner once construction is underway. This information includes the number of claims occurring in the project, the amount claimed per claim, and the probability of effectively settling these claims given the actual project conditions and relationship between the owner and the contractor. This information will allow the owner to more realistically assess the resources required to settle these claims during construction and avoid their escalation to post-construction disputes.

Table 2 below summarizes the different parameters/variables used to develop the model based on the analogy with the construction project model and Figure 4 shows the schematic model.

Table 2: Notations and assumptions

Construction project model (Majd and Pindyck 1987)		**ADR investment model**	
V:	Value of the completed construction project	**S:**	Expected cost savings in project
V*:	Optimal investment value of the completed project as a function of the remaining investment cost	**S*:**	Optimal investment value of the expected cost savings in the project as a function of the remaining ADR investment cost
K:	Total construction cost spend at a maximum rate *k*	**I:**	Total desired ADR investment spend at a maximum rate *i*
r:	Risk free interest rate	**r:**	Risk free interest rate
σ:	Instantaneous deviation of project value	**σ:**	Uncertainty surrounding the expected cost savings in project
δ:	Opportunity cost	**δ:**	Opportunity cost of not having the option to invest in ADR
C(V):	Option value of the completed project	**F(S):**	Option value of the ADR investment

The uncertainty value σ and opportunity cost δ represent the uncertainties resulting from both the project-specific and ADR-specific risks. The values of these parameters as stipulated in the model depend on the owner's perception of the level of risk associated with the project and ADR process itself. The variation in the values of σ is shown in Table 3 below. These expected values of σ need to be verified by analysing historical data related to claims occurring in different types of projects.

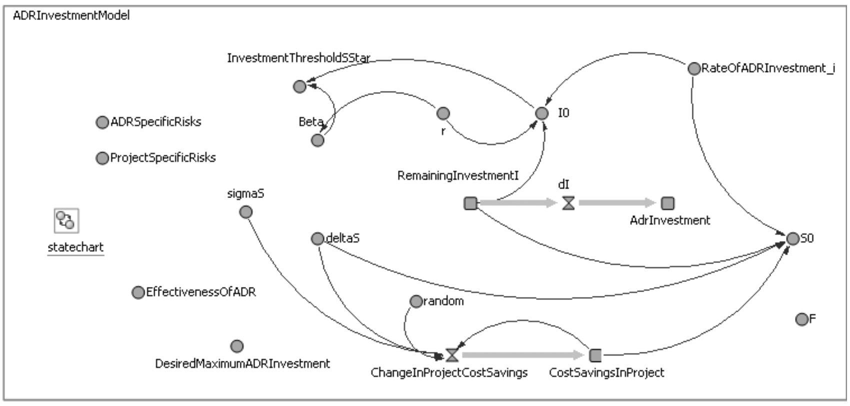


Figure 4: ADR investment model

The opportunity cost δ varies with the effectiveness of the ADR as shown in Figure 5. This figure shows that the effectiveness of the ADR is in turn a function of the ratio of the desired maximum investment of the ADR to the expected cost savings in the project.

Table 3: Values of σ based on perceived level of risk

		Project-specific risks		
		High	**Medium**	**Low**
ADR -specific risks	**High**	75%	60%	50%
	Medium	60%	50%	40%
	Low	50%	40%	25%

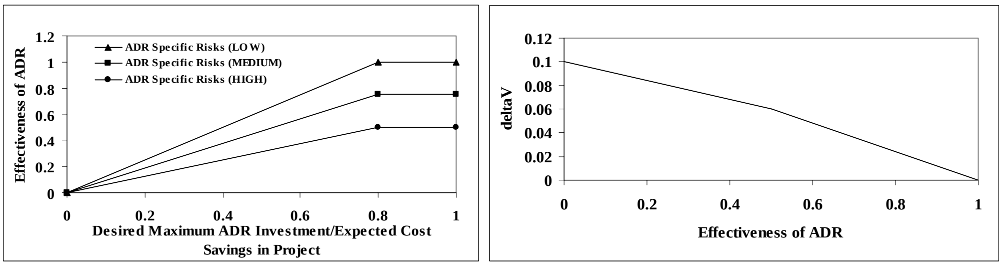


Figure 5: Variation in ADR effectiveness and δ

In running the model, the user can input the expected cost savings in the project, the desired maximum ADR investment, the desired maximum rate of ADR investment, as well as the project-specific and ADR-specific risks. The model simulation will result in variation in the expected cost savings during the life of the project, the proposed ADR investment profile and the investment value. Figure 6 shows an example of the model input and simulation. In this example, the owner estimates the expected cost savings in the project due to a given ADR process to be $1 000 000. The desired maximum investment in the ADR is set to $500 000 to be spent at a maximum rate of $40 000 per year over a period of 10 years. The owner perceives the project-specific risks to be medium while the ADR-specific risks are set to high. The simulation of the model under these input parameters indicates that the investment value is always positive, and thus investment in the ADR proceeds at a constant rate of $40 000 per year as seen in the ADR investment profile graph in Figure 6.

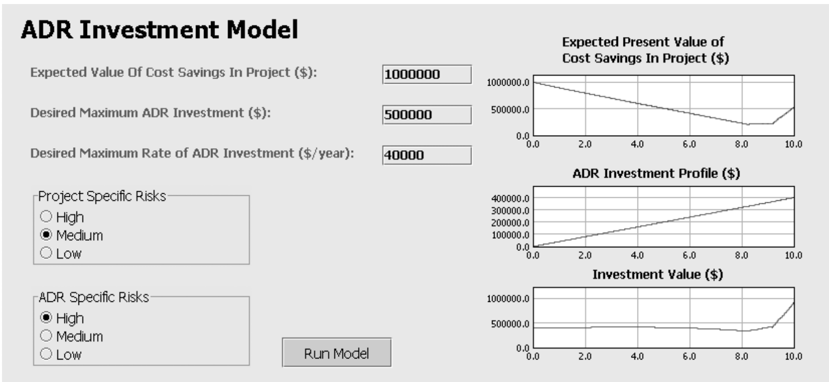


Figure 6: ADR investment model simulation window

CONCLUSION

This paper investigated the application of real option valuation when there is time to build to evaluate ADR investments in construction projects. A system dynamics model is presented that takes into account the uncertainties surrounding the ADR investment cash flows; as well as the project-specific and ADR-specific risks. It is perceived that such a model will guide ADR investment decisions regarding the amount and timing of such investments.

The future research will focus on developing the presented model to take into account different levels of any dispute resolution process. Also, extensive research and data analysis are currently underway to determine estimates for the parameters of the model. Finally, the model shall be validated through application to a real construction project and comparing real time data to those obtained from the model.

REFERENCES

Adrian, J (1988) *Construction claims: a quantitative approach.* Prentice Hall.

AGC (Associated General Contractors of America) (2000) *Enlightened risk allocation – the 21st century owner's guide to cost effectiveness*, available at www.agc.org/ (accessed 15 January 2006).

AGC (Associated General Contractors of America) (2003) Contractors blitz Capitol Hill. *Construction News*, 16 September 2003, 1.

AGC (Associated General Contractors of America) (2006) *Quick facts about the construction industry*, available at www.agc.org/galleries/economics/Quick%20Facts071006.doc (accessed 22 August 2006).

Black, F and Scholes, M (1973) The pricing of options and corporate liabilities. *Journal of Political Economy*, **81**(3), 637–54.

Boute, R, Demeulemeester, E and Herroelen, W (2004) A real options approach to project management. *International Journal of Production Research*, **42**(9), 1715–25.

Caltrans (California Department of Transportation) (2000) *Field guide to partnering on Caltrans projects.* Caltrans, April 2000.

Clough, R, Sears, G and Sears, S (2005) *Construction contracting: a practical guide to company management.* 7ed. Hoboken, NJ: John Wiley and Sons, Inc.

Espinoza, R D and Luccioni, L X (2005) An approximate solution for perpetual American option with time to build: the value of environmental remediation investment projects. Paper presented at the Real Options 9th Annual International Conference, Paris, France.

Fenn, P, O'Shea, M and Davies, E (1998) *Dispute resolution and conflict management in construction: an international review*. London: E & FN Spon.

Fichman, R, Keil, M and Tiwana, A (2005) Beyond valuation: option thinking in IT project management. *California Management Review*, **47**(2), 74–96.

Hanna, A and Gunduz, H (2004) Impact of change orders on small labor-intensive projects. *ASCE Journal of Construction Engineering and Management*, **130**(5), 726–33.

Hull, J (2000) *Options, futures, and other derivative securities*. 4ed. Englewood Cliffs, NJ: Prentice Hall.

Luehrman, T (1995) Capital projects as real options: an introduction. Harvard Business School Note 295-074.

Luehrman, T (1998) Strategy as a portfolio of real options. *Harvard Business Review*, **76**(5), 89–99.

Majd, S and Pindyck, R (1987) Time to build option value and investment decisions. *Journal of Financial Economics*, **18**, 7–27.

Pena-Mora, F, Sosa, C and McCone, D (2003) *Introduction to construction dispute resolution.* Upper Saddle River, NJ: Prentice Hall.

Samuelson, P A (1965) Proof that properly anticipated prices fluctuate randomly. *Industrial Management Review*, **6**(2), 41–9.

Trigeorgis, L (1993) Real options and interactions with financial flexibility. *Financial Management*, **22**(3), 202–24.

Trigeorgis, L (1996) *Real options managerial flexibility and strategy in resource allocation*. Cambridge, MA: MIT Press.

Trigeorgis, L (1996) *Real options managerial flexibility and strategy in resource allocation*. Cambridge, MA: MIT Press.

USACE (United States Army Corps of Engineers) (1989) *Appendix A, Part 3 – Contract, requests, claims, and appeals*, available at www.usace.army.mil/usace-docs/ (accessed March 2006).

CONSTRUCTION PROJECT CLAIMS AND CONFLICT IN SINGAPORE

Ajibade Ayodeji Aibinu[1]

Faculty of Architecture, Building & Planning Old Commerce Building, Room 402 The University of Melbourne, Victoria 3010 Australia

Resolving a construction contractor's claims is a complex and difficult process. It could generate conflict and, ultimately, costly dispute resolution during the construction process. This study explores the extent to which nine potential issues of disagreement were responsible for conflict when resolving claims on 41 construction projects in Singapore. It also investigates the overall frequency and severity of disagreements on each project, how most disagreements were terminated and the impact on the contractors' attitudinal propensities and relationship with the employer. The results shows that in about 68% of the projects, the EoT claims requested by the contractors was more than 10% of the original contract duration while in 40% of the projects the additional cost requested by the contractors was more than 15% of the original contract sum. In more than half of the projects (56.09%), the contractors were awarded more than 60% of the amount of EoT claims requested while more than 60% of the additional cost claims requested were awarded to the contractors in less than half of the projects (41.46%). Disagreements arose more frequently on the quantum of the contractor's entitlements. This was followed by criticality of delay, responsibility for delay, whether work giving rise to claims was required by the contract or was extra work, type and amount of information used in substantiating claims, whether or not the contractor actually incurred added cost, contract interpretation, concurrency of delays and methodology/technique used in substantiating and assessing claims. One-sample t test analyses suggest that, overall, disagreements were very frequent and moderately severe on the projects. Analysis further revealed that in 41.5% of the projects, disagreements were mostly resolved by mutual consent, while in 43.9% the contractors compromised their position so as not to engage in formal dispute. The employer's position was imposed on the contractor in 14.6% of the projects. One-sample t test analyses further suggest that on projects where most of the conflicts were terminated by mutually agreed upon solution, working relationship was moderately affected. Negative attitudinal propensities such as the contractor's potential to reject the outcome and potential to dispute were also moderate. Whereas projects where most of the conflicts were terminated by the contractors' compromise or by the employers' imposition of a decision on the contractors, relationships were moderately affected. However, the contractors indicated a very high level of negative attitudinal propensities. Among other things, the findings suggest that when parties focus on finding a mutually acceptable solution to claims – rather than a one-sided compromise or forceful imposition of a decision – disagreements may have a moderate impact on a contractor's negative attitudinal propensities and thereby overall performance of the project and the construction industry at large.

Keywords: claims, conflict, contract administration, cost, time.

[1] aaibinu@unimelb.edu.au

INTRODUCTION

Claims and conflicts are major sources of inefficiency in the delivery of construction projects (Latham 1994). In the United Kingdom, contractors' claims for extension of time (EoT) and loss and expenses claims are the second and fourth most frequent subjects of litigation between the main contractors and employers (Russel 2001). The problem of claims, conflict and dispute has also been reported in other countries (Jergeas and Hartman 1994 – Canada; Uher 1994 – Australia; Barrie and Paulson 1992 – USA). Wong, (2005) reported that contractors' claims for variation and project delays are the first and second most frequently disputed issues in Singapore. Reaching reasonable settlement of claims in an effective, economical and timely manner is difficult (Barrie and Paulson 1992).

One of the reasons is that substantiating and assessing construction claims are complex and subjective, involving numerous assumptions (Perlman 1984). Claims also involve strong underlying conflict of interest between the employer (building owner or the client), contractor and the person certifying the claims. Thus, claims could generate conflict and dispute that may be costly and time-consuming (Diekman *et al*. 1994). Robinson *et al*. (1996) observed some increasing trend of contentious behaviour in Singapore and Malaysia construction industry.

The aim of this study was explore the levels of claims on some construction projects in Singapore, assess the extent to which nine potential issues were responsible for conflict in the handling of claims and, in that regard, assess the intensity of conflict generated, the mode by which the conflicts were terminated during negotiation, and the impact of the conflicts on relationship between the parties involved and on the contractors' attitudinal propensities. The results provide useful information to construction industry stakeholders on claims and conflict climate in the Singapore construction sector. Useful information is provided for reducing potential for contract dispute and breakdown of working relationship when resolving claims. The results are of international application in that construction sector in most countries are faced with similar problems.

PROJECT CLAIMS AND CONFLICT

For the purpose of this study, a claim refers to any application by the main contractor to the engineer (or architect) pursuant to any relevant clause of the contract – for any additional payment, extension of time and or damages for any alleged breach of duty by the employer (client) and the engineer (or architect) (Kumaraswamy and Yogeswaran 1998). The process for administering claims may be accompanied by conflict in the form of disagreements with claims certifier's decision, hostility and negative attitudinal propensities of the parties involved (March and Simon 1958; Pondy 1967).The reason is that resolving claims involves questions that potentially have commercial implication for employer and the contractor. The questions include (Perlman 1984): should the construction period be extended because of the claim event and, if so, should the contractor be paid for additional cost? And if an extension of time is inappropriate, should the contractor be required to pay liquidated damages?

When attempting to address these questions, conflict may escalate and grow in intensity. Intensity is an important conflict characteristic (Bercovitch and Langley 1993). According to Yiu and Cheung (2005), when tension level reaches a threshold in construction conflict, the conflict level would be high even if the tension level subsides and the conflict may not return to the original level. Thus, conflict intensity may influence negative attitudinal propensities of parties involved. Negative attitude may be in the form of the potential to reject the outcome and formally dispute claims. Conflicts may also damage the working relationship between the parties. In this study, conflict intensity is measured by two items: frequency and severity of disagreements during the process for administering claims (Diekman *et al*. 1994; Bercovitch and Langley 1993; Kressel and Pruitt 1989).

CONFLICT ISSUES IN THE HANDLING OF CLAIMS

In process for administering claims, the claims certifier is expected to form a view on the validity of the contractor's claims and make recommendation on the quantum of the contractor's entitlements. To enable the claims certifier to form his/her view, the following questions of facts that are potential causes of disagreements are typically addressed (Perlman 1984):

1. Whether or not the works giving rise to claims is required by the contract or is extra work
2. Whether the delay is due to the contractor's inefficiency or the employer's or his/her representative's actions (hereafter referred to as *Responsibility for delays*)
3. Whether the delay is on the critical path (hereafter referred to as *Criticality of delays*)
4. Whether the employer-related delay is concurrent with another contractor-related delay (hereafter referred to as *Concurrency of delay*)
5. Whether or not the contractor actually incurred added costs.

There use of different approach to claims substantiation and assessment may also constitute an area of disagreements (Zack 2002). There are different methodologies that may be used for substantiating extension of time (EoT) claims by the contractor, upon which the claims certifier then assesses the claims, also using one or more of the varieties of methods. The use of different information and methodology by the contractor and claims certifier to substantiate and assess claims respectively would produce different results and conclusion (Kumarswamy and Yogeswaran 2003; Zack 2002) and thereby high potential for conflict and dispute. Where claims involve issues of facts, making a fair and reasonable decision would depend on the type and quality of information available (Jergeas 2001). Reaching a decision on claims would also depend on the interpretation of contract provisions relating to EoT and additional cost claims. Sometimes, contract terms are ambiguous and incomplete and may be a subject of heated argument (Spittler and Jentzen 1992). Thus, the following are other potential issues that could generate disagreements:

6. The type and amount of information used in substantiating claims
7. The methodology and technique used in substantiating and assessing claim
8. The quantum of contractor's entitlements
9. Contract interpretation.

There may be three modes by which parties could terminate conflict during negotiation of claims, namely forcing a decision on the contractor, mutual agreement between the parties and a compromising mode where one or both parties compromise their initial position (McDuff and Ray 2002). Terminating conflict by mutual agreement is collaborative and may yield an outcome that accommodates the interest of the contractor and the employer. Thus, it may lessen negative attitudinal propensities and reduce damage to parties' relationship. Compromise may de-escalate conflict but may lead to dissatisfaction and negative attitudinal propensities especially where a contractor compromises because of fear of damage to its reputation and potential loss of future jobs from other clients. Forcing a decision on the contractor may lead to further escalation of conflict, damage the contractor's relationship with the employer and/or may generate negative attitudinal propensities.

DATA AND METHODOLOGY

Data was obtained through a questionnaire survey of main contractors' contracts managers and quantity surveyors in Singapore who have experience with handling of claims. The respondents were employees of selected sample of construction firms operating in Singapore. The firms were selected from the contractor's registry of the Singapore Building and Construction Authority (BCA). The BCA is an authoritative source documenting the names and addresses of construction contractors serving the procurement needs of government departments, statutory bodies and other public sector organizations in Singapore. Two hundred contractors belonging to the grades A1, A2 and B1 under the Construction WorkHead CW01 – General Building and Construction WorkHead CW02 – Civil Engineering categories were selected for the data collection. The grades A1, A2 and B1 are classified based on the tendering limit as follows: A1 – unlimited, A2 – 65 million dollars and B1 – 30 million dollars respectively. Thus, contractors in categories A1, A2 and B1 are big players with technical and management expertise.

The respondents were asked to base responses on their experience, attitudes and attitudinal propensities in the process for administering claims on a project of their choice. The questions were designed to measure the level of claims requested and level of claims allowed. Other items were measured on a Likert-type scale ranging from 1 to 7. The frequency to which each of the nine issueswere responsible for disagreements was measured on response options ranging from 1 representing "least often" to 7 representing "most often". The overall frequency of conflict was measured with response options 1 representing "rarely" to 7 representing "very frequent". Severity of conflict was measured with response options ranging from 1 representing "minimal" to 7 representing "very severe". The respondents were also asked to indicate how most of the conflicts were terminated by selecting from among three options: (1) "Most of the solutions were mutually agreed upon"; (2) "Most of the decisions were imposed on us (the contractor)"; (3) "In most cases, we (the contractor) compromised our position so as to reach a solution and not engage in dispute".

Two attitudinal propensities of the contractor were also measured as follows: the potential to reject the final outcome and the potential to dispute were measured by response options 1 representing "low" to 7 representing "high". The extent of damage to working relationship with the employer was also measured on scale 1 representing "low" to 7 representing "high". The data obtained from the questionnaire were analysed. The results are presented next.

DATA ANALYSIS AND RESULTS

Responses to the survey

Of the 200 contractors contacted, 41 responded – representing a response rate of 20.5%. A total of 32% were foreign construction firms operating in Singapore while 68% were local firms. However, the 41 respondents from the 41 firms were Chinese, except one who was German. In addition, 41.5% were contract managers while another 41.5% were quantity surveyors. A total of 17% were either project managers or site managers. A total of 70% of them had over 11 years' experience in construction while 65.85% have been involved in over 11 projects in the past. Further, 63% of the projects upon which the responses were based are building projects while 37% are civil engineering projects. A total of 51.2% were procured by the public sector clients while 48.8% were procured by private clients. In terms of the conditions of contract used, 51.2% of the projects made use of the Public Sector Standard Conditions of Contract (PSSCOC) while 48.8% were procured with the Singapore Institute of Architect Conditions Contract (SIA).A substantial number of the projects (43.9%) are above 65 million dollars in value.

Level of claims requested by the contractors

Table 1 shows the levels of extension of time (EoT) and additional cost claims requested by the contractors. In 68.2% of the projects, the EoT claims requested were more than 10% of the original contract duration while in about 40% of the projects the additional cost requested by the contractors was more than 15% of the original contract sum.

Table 1: Extension of time (EoT) and additional cost claims requested by the contractors

% of contract duration	EoT claims requested			Additional cost claims requested		
	Frequency	**%**	**Cumulative percentage of projects**	**Frequency**	**%**	**Cumulative percentage of projects**
40% and above	4	9.75	9.75	3	7.32	7.32
30% and up to 39.99%	1	2.44	12.19	3	7.32	14.64
20% and up to 29.99%	7	17.07	29.26	2	4.87	19.51
15% and up to 19.99%	5	12.20	41.46	3	7.32	26.83
10% and up to 14.99%	11	26.83	68.29	5	12.20	39.03
5% and up to 9.99%	3	7.32	75.61	13	31.71	70.74
0.1% and up to 4.99%	10	24.39	100	12	29.26	100
Total	41	100		41	100	

Level of claims awarded/granted by the employers

Table 2 shows the percentage of the EoT and addition cost claims requested by the contractors which were awarded by the employers. In about 56% of the projects, the EoT claims awarded were above 60% of the amount requested while in the remaining 44%, the EoT awarded were less than 45% of the amount requested. More than 60% of the additional cost claims requested were granted in 41.46% of the projects while less than 60% of amount requested were granted in about 58.54% of the projects. The outlook is that in more than half of the projects surveyed, the contractors were awarded more than 60% of the amount of EoT claims requested while more than 60% of the additional cost claims requested were awarded to the contractors in less than half of the projects (41.46%). Success rate for EoT surpass that of additional cost claims. During the questionnaire interview, some of the respondents pointed out that in many cases they were awarded EoT but were asked to abandon their request for additional cost claims.

Table 2: Extension of time (EoT) and additional cost claims awarded by the employer

% of amount requested	EoT claims awarded			Additional cost claims awarded		
	Frequency	%	Cumulative percentage of projects	Frequency	%	Cumulative percentage of projects
90% and up to 100%	12	29.26	29.26	4	9.75	9.75
75% and up to 89.99%	9	21.96	51.22	6	14.64	24.39
60% and up to 74.99%	2	4.87	***56.09***	7	17.07	***41.46***
45% and up to 59.99%	6	14.64	70.73	6	14.64	56.10
30% and up to 44.99%	1	2.44	73.17	1	2.44	58.54
15% and up to 29.99%	2	4.87	78.04	8	19.50	78.04
0.1% and up to 14.99%	9	21.96	100	9	21.96	100
Total	41	100		41	100	

During the interview, all the respondents except one reported that when cost claims are granted, the same amount certified were paid by the employer. In the defiant case, the respondents reported that the employer refused to pay despite the fact that the cost claims were certified. At the time of the interview, the case was still under negotiation. However, the respondent indicated that if negotiation fails, the case would be pursued with formal dispute resolution because of the commercial implications of the amount involved. The analyses of the level of claims requested and awarded (Tables 1 and 2) are based on the information obtained on projects selected by the respondents. It is possible that respondents selected projects with larger claims, so the analyses presented may be an incomplete picture of the overall claims level in

Singapore. However, given that the respondents are personnel of big players in the Singapore industry, the result is indicative of claims levels in Singapore and, of more importance to this study, it is reflective of the claims level on the projects surveyed.

Conflict issues

The mean of the scores assigned by the respondents to each of the nine conflict issues was estimated and ranked. The results (Table 3) show that quantum of claims is the most frequent issue responsible for disagreements (1^{st}). This is not surprising when one considers the fact that construction contracts are commercial transactions and parties would desire to maximize returns. The question of criticality of delay is the next most frequent issue of disagreements (2^{nd}). In a delays claims process, a contractor's entitlement to EoT would depend on the question of whether the delay event is on the critical path and whether it contributes to the overall project delays. The question of criticality could be an area of argument especially where the construction programme is not progressively and consistently updated and monitored. Following disagreements on criticality of delays, disagreement regarding responsibility for the event causing the claims ranked third (3^{rd}). This is not surprising because when claims events occur, liability for the event is typically allocated to the party responsible for the event. Given the complex nature of construction activities, interdependency of roles and responsibilities and the high conflict of interest among the parties in a construction contract, arguments relating to responsibility for claims events are likely to be an area of frequent disagreements.

Table 3: Mean score and ranking of conflict issues

Issue	Mean Score	Rank
The quantum of contractor's entitlements	5.41	1
Criticality of delays	5.24	2
Responsibility for delays	4.73	3
Whether or the not the works giving rise to claims was required by the contract	4.71	4
The type and amount of information used in substantiating claims	4.59	5
Whether or not the contractor actually incurred added cost	4.46	6
Contract interpretation	4.27	7
Concurrency of delays	4.20	8
The methodology and technique used in substantiating and assessing claims	3.90	9

Disagreements on whether the works giving rise to the claims was required by the contract ranked next (4^{th}) to disagreement on responsibility for delay. This is also an important aspect of claims process, which is needed to determine the validity of contractor's claims and the quantum of the entitlements. This frequency may depend on the level of completeness of contract documents prior to the execution of contract agreement. Disagreements on type and amount of information ranked fifth (5^{th}). This was followed by disagreement on whether or not additional cost was incurred (6^{th}), issues of contract interpretation (7^{th}) and concurrency of delays (8^{th}). The problem with methodology/approach used in calculating claims ranked lowest (9^{th}).

Intensity of conflict

A one-sample t test was conducted to determine the overall intensity of conflict (measured by the overall frequency of disagreements and the severity of the disagreements). The t test was conducted to ascertain whether the mean score of the two items were significantly different from 4 (midpoint representing "moderately frequent" and "moderately severe" on the Likert scale of 1 to 7). The results (Table 4) show that the mean frequency of disagreements (4.68) is significantly different from 4 (p = 0.006). However, the mean severity of the disagreements (4.02) is not significantly different from 4 (p = 0.920). The results suggest that the disagreements were very frequent but were moderately severe.

Table 4: Results of one-sample t test for intensity of conflict (test value = 4)

Items	Mean	t value	Sig. (2-tailed)
Frequency of disagreement	4.6829	2.901	p = 0.006
Severity of disagreement	4.0244	0.101	p = 0.920

Termination of conflict

Data on how conflicts were terminated was analysed. Table 5 shows that in 41.5% of the projects conflicts were terminated by a mutually agreed upon solution during negotiation, while in 43.9% of the cases the contractor compromised its position so as not to engage in dispute and to protect its reputation. Most of the decisions on claims were forced on the contractor in 14.6% of the projects.

Table 5: Termination of conflict

Mode of termination of conflict	Number of cases	% of total
Most of the solutions were mutually agreed upon	17	41.5
In most cases the contractor compromised its position so as to reach a solution and not engage in dispute.	18	43.9
Most of the decisions were imposed (forced) on the contractor	6	14.6

The result suggests that in most of the projects, conflicts were terminated in two dominant modes namely: compromise by the contractors and mutual agreement between the parties. The dominance of the comprising mode (43.9%) may be due to the size of the Singapore construction market and cultural influences (Chinese culture). Chinese culture and traditional values tend to prefer to avoid conflict in the belief that maintaining relationship is necessary for sustaining good will and ensuring future cooperation (Cheung and Chuah 1999) and for securing future work.

Effect of disagreements on relationship and contractors' attitudinal propensities

It was expected that the impact of the disagreements on working relationships, the contractor's potential to reject the outcome of claims and contractor's potential to dispute the outcome of the claims would vary across the three modes of conflict termination (see Table 5). A t test was conducted to check if the mean scores of each of these items were significantly different from the midpoint of 4. The results (Table 6) show that where conflict was terminated by mutual solution and mutual agreement, the impact of the conflicts on parties relationship was moderate (mean 3.41, p = 0.116). Negative attitudinal propensities were also moderate (for potential to reject the outcome, the mean = 3.88, p = 0.811; for potential to dispute the mean = 3.71 with a p value of 0.569).

Table 6: Results of one-sample t test for the impact of disagreements on parties' relationship and contractors' attitudinal propensities (test value = 4)

Conflict termination mode	**Impact of disagreement on working relationship**	**Contractor's potential to reject decision**	**Contractor's potential to dispute**
By mutual agreement (n = 17)	Mean score = 3.41 t value = -1.661 p = 0.116	Mean score = 3.88 t value = - 0.243 p = 0.811	Mean score = 3.71 t value = - 0.582 p = 0.569
By contractor's compromise (n= 6)	Mean score = 4.50 t value = 1.40 p = 0.177	Mean score = 5.05 t value = 3.12 p = 0.006	Mean score = 5.05 t value = 2.491 p = 0.023
Solution imposed on the contractor (n= 18)	Mean score = 4.83 t value = 1.38 p = 0.177	Mean score = 5.50 t value = 4.39 p = 0.007	Mean score = 4.67 t value = 1.195 p = 0.286

Where most of the conflicts were terminated by contractors' compromise, the impact on contractors' relationship with the employers was also moderate but they indicated a very high negative attitudinal propensities (for potential to reject the outcome the mean = 5.05, with a p value of 0.006; and for potential to dispute the mean = 5.05 with p = 0.023). Where a solution was imposed on the contractor, the impact on the relationship was moderate whereas the contractors indicated a very high potential to reject the outcome (mean = 5.50, p = 0.007) but moderate potential to dispute (mean = 4.67, p = 0.286).

CONCLUSION

This study has explored the nature of claims and conflict in Singapore. It has shown that success rate for EoT claims surpass that of additional cost claims. Most often, the first three issues responsible for disagreements include quantum of claims, questions of criticality of delay and responsibility for the event causing the claims. The three issues reflect the general believe that stakeholders in the construction industry are self-interested and seek to maximize their gain. It also reflects the problematic complexity of construction projects and interdependency of construction activities and their influence on conflict. These characteristics are justifiable given that construction is a commercial transaction among economically dependent organizations. Nevertheless, when conflict arises, their impact on negative attitudinal propensities of parties involved may be reduced by finding a settlement that is mutually acceptable and focuses on the needs of all parties involved – rather than imposing or forcing a decision on a party or by compromise of one party. Attempting to impose or force a decision on a party is a win/loose approach, one sided, adversarial, threatening and aggressive in nature. It may generate costly contract disputes. Although Chinese culture and traditional values mean that conflict is sometimes avoided in the belief that maintaining good relationships is necessary for sustaining good will, ensuring future cooperation (Cheung and Chuah 1999) and for securing future work, the results of this study suggests that the compromise mode for terminating conflicts may be counterproductive. Compromising by making concessions for the sake of reputation or a relationship is one sided. It is a win/lose situation that makes the compromising party ignore its won needs in order to meet the needs of the other party. The compromising party may suffer losses and become dissatisfied. This may generate a very high propensity for negative attitude and may encourage adversarial culture in future contract relationships. Mutual settlement focuses on parties' respect for one another's interests. It leads to a win/win solution and could lead to a long-lasting relationship on the project. These conclusions provide vital information for stakeholders in Singapore construction sector where withdrawing/avoiding and the compromise style of conflict handling is dominant. The findings are also applicable to other countries.

REFERENCES

Barrie D S and Paulson B S (1992) *Professional Construction Management*. 3ed. New York: McGraw-Hill.

Bercovitch, J and Langley, J (1993) The Nature of Dispute and the Effectiveness of International Mediation. *Journal of Conflict Resolution*, **37**(4), 670–91.

Cheung, C C and Chuah, K B (1999) Conflict management styles in Hong Kong industries. *International Journal of Project Management*, **17**(6), 393–9.

Diekman, J, Girard, M and Abdul–Hadi, N (1994) Disputes Potential Index : A study into the Predictability of Contract Disputes. *Construction Industry Institute, Source Document 101*, The University of Texas at Austin, TX.

Jergeas, G F (2001) Claims and Disputes in the Construction Industry. *AACE International Transactions*, CDR.03.1-CDR.03.4.

Jergeas, G F and Hartman, F T (1994) Contractors' Construction-Claims Avoidance. *Journal of Construction Engineering and Management ASCE*, **120**(3), 553–60.

Kressel, K and Pruitt, D (1989) Conclusion: A research perspective on the mediation of social conflict. *In*: K Kressel and D G Pruitt (Eds.) *Mediation Research*. San Francisco: Jossey-Bass.

Kumaraswamy, M H (1998) Consequences of construction conflict: a Hong Kong perspective. *Journal of Management in Engineering*, **14**(3), 66–74.

Kumarswamy, M M and Yogeswaran, K (2003) Substantiation and Assessment of Claims for Extensions of Time. *International Journal of Project Management*, **21**, 27–38.

Latham,M (1994) *Constructing the Team: Final report of the Government/industry Review of Procurement and Contractual Arrangements in the UK Construction Industry*. London: HMSO.

McDuff, C R and Ray, M C (2002) Total cost construction claims tactics. *AACE International Transactions* (January 1), CD111–CD113.

March, J G and Simon, H A (1958) *Organizations*. New York: Wiley.

Perlman, M S (1984) Contractor's Claims for Delay. *International Construction Law Review*, **1**, 3–15.

Pondy, L R (1967) Organisational Conflict: concepts and models. *Administrative Science Quarterly*, **12**, 296–320.

Public Sector Standard Conditions of Contract for Construction Works (PSSCOC) (now in its fifth edition).

Robinson, N M, Lavers, A P, Tan, G K H and Chan, R (1996) *Construction Law in Singapore and Malaysia*. 2ed. Singapore: Butterworths Asia.

Russell, V. (2001). Trends and Developments in the Resolution of construction disputes: A paper based on a talk given to a meeting of the Society of Construction Law, Belfast, 15 February 2001.

Singapore Institute of Architects (1999) *Articles and Conditions of Building Contract*. 6ed. Singapore: Singapore Institute of Architects.

Spittler, J R and Jentzen, G H (1992) Dispute resolution: managing construction conflict with step negotiations: *AACE Transactions*, **D9**, 1–10.

Uher, T E (1994) What is Partnering. *Australian Construction Law Newsletter*, **34**, 49–61.

Wong, Y L (2005) *Factors Affecting the Choice of Dispute Resolution Methods*, Unpublished Bachelors dissertation, National University of Singapore.

Yiu, K T W and Cheung, S O (2006) A catastrophe model of construction conflict behaviour. *Building and Environment*, **41**(4), 438–47.

Zack, G J (2002) Calculation and recovery of home/head office overhead. *Paper presented at the 3rd World Congress on Cost Engineering, Project Management and Quantity Surveying and 6th Pacific Association of Quantity Surveyor's Congress*, 14–18 April, 2002, Melbourne Australia. International Cost Engineering Council.

ALTERNATIVE DISPUTE RESOLUTION: SUGGESTIONS FOR APPLICATION IN THE TURKISH CONSTRUCTION INDUSTRY

Deniz Ilter[1], Attila Dikbas[1] and Mel Lees[2]

[1]*Project Management Center, Istanbul Technical University, Maslak, Istanbul*
[2]*School of the Built Environment, University of Salford, Salford, UK*

Dispute is a common occurrence in the construction industry, and litigation, the formal way of settling disputes, is time-consuming and expensive besides several other drawbacks. This has led the authorities and the industry to seek and establish non-judicial dispute settlement methods in quest for more cost-effective and swifter solutions that prevent deterioration of business relations between the parties. Such alternatives to litigation are generically called alternative dispute resolution (ADR) methods. The ADR approach has been widely adopted by the EU, and considering Turkey's EU accession process as well as the need for low-cost and non-bureaucratic methods of dispute resolution, a genuine need exists to identify the legislative and the institutional pre-requisites for adoption and practise of ADR methods in the Turkish construction industry. Based on the conceptual framework proposed by Esman, the fundamental criteria are developed and formulated for the institutionalization of ADR in the Turkish construction industry in accordance with EU directives. This study aims to be a timely contribution to the process of the establishment of ADR in the Turkish construction industry, and the fundamental criteria set forth in this study are contemplated to serve as basis for an implementation model to be developed in subsequent studies.

Keywords: alternative dispute resolution, institutional development, Turkish construction industry.

INTRODUCTION

Disputes, as Cheung *et al*. (2002) suggest, are frequently the rule rather than exception in the construction industry and they arise for a number of reasons. The quality of materials, standard of workmanship, contractor delays, applications for extensions of time not being granted, variations, cost overruns and the meaning of contractual terms can be the subject of expensive claims and turn into disputes that threaten the success of the project (Adriaanse 2005). This poses a serious risk to a construction project for all parties if the disputes are not resolved before going to court, as litigation is a long, expensive and acrimonious process. In order to avoid litigation in dispute resolution, a range of 'alternative dispute resolution' (ADR) methods are widely used in the construction industry and have become an important issue of construction research and literature in the last decades.

ADR is a non-adversarial technique that is aimed at resolving disputes without resorting to the traditional forms of either litigation or arbitration (Ashworth 2005: 53). It is defined in the European Commission's Green Paper (2002: 6) as "out-of-

[1] artande@itu.edu.tr

court dispute resolution processes conducted by a neutral third party excluding arbitration". The most widely used ADR methods are mediation, conciliation, adjudication and dispute review boards/panels. The discussion on arbitration in the literature seems to result in defining arbitration not as an ADR method but a quasi-judicial procedure because of its features that are closer to (or worse than) litigation in terms of duration, cost and the level of bureaucracy (EC Green Paper 2002: 6; Adriaanse 2005: 347; Carmichael 2002: 265). The European Commission's Green Paper also suggests that expert opinion process should not be considered as a dispute resolution method as it is a procedure involving recourse to an expert in support, usually in litigation or arbitration. In this paper, the definition by the European Commission's Green Paper is followed and Alternative Dispute Resolution methods are referred to by the acronym "ADR", following the already widespread practice.

Rubin and Quintas (2003) suggest that the salient characteristics of ADR make it an attractive option for settling the complex and time-sensitive disputes that often arise during the course of construction projects. Beside being a faster, less bureaucratic and more cost-effective process that does not require the use of attorneys to present claims, the real-time approach to disputes can prevent deterioration of business relations. In addition, the consideration of disputes by knowledgeable industry professionals can achieve more equitable results based on the realities of the construction process instead of applying the strict letter-of-the-law removed from its relevant context.

The negative perceptions of the use of ADR in the construction industry have been analysed by Brooker and Lavers (1997) on the basis of an extensive survey in the UK construction industry, which identified the following most frequently stated negative attitudes to ADR: (i) proposing ADR to the other side is a sign of weakness; (ii) ADR reveals one's position to the other side; (iii) ADR before discovery of documents could result in a settlement being entered into when one should have gone for something better; (iv) ADR can be used to delay payment; and (v) ADR is non-binding and therefore too weak to be effective (for non-binding methods of ADR). Despite these negative perceptions, Broker and Lavers (1997) conclude that the widespread dissatisfaction with its long-established 'rivals' speaks in favour of ADR. Many respondents who had never used ADR expressed an interest in doing so and ADR was perceived as enjoying real advantages over litigation and arbitration, in terms of reduction of damaging confrontation, reduced cost and time, and the expectation of flexibility and a good settlement rate.

ADR is widely used in many countries' construction industries and is spreading fast globally (Cheung 2006). However, although the benefits of ADR are widely appreciated, as Cheung (2006) suggests, the adoption and implementation of such new methods is obstructed by the relevant laws, regulations and the absence of adequate institutions. Therefore, resolute government policies for both the adaptation of the legislation and the institutional development are required for viable implementation.

In tune with the initiatives by the EU agencies to establish and promote the ADR methods, this paper develops a set of fundamental criteria for the institutional framework to adopt ADR in the Turkish construction industry, based on an assessment of the current problems of the industry associated with dispute resolution and an outlook of the related legislation.

A REGULATORY FRAMEWORK FOR ADR

A regulatory framework with two aspects is needed for the implementation of ADR. First, despite its informal structure, the proper functioning of ADR depends on a sound relationship between legislation and ADR. The ADR mechanisms are legally empowered when they or their outcomes are recognized by law. The second aspect is the planning and the creation of an institutional framework for implementation, governing the policies and the rules associated with ADR. Buyck (1991) offers a definition for institutional development as the creation or reinforcement of the capacity to generate, allocate and use human and financial resources effectively to attain development objectives, public or private. It includes the building, strengthening, retrenchment or liquidation of institutions in the pursuit of institutional, sectoral or government-wide realization. From the perspective of developing countries, such as Turkey, institutional development is seen as more essential for the development of construction industries (McDermott and Quinn 1995). Kaming *et al*. (1994) describes institutional development as one of the key strategies in identifying the common problems of the construction industries in developing countries and strategic responses thereto. Being a candidate state, Turkey is following EU doctrine in the institutional development process of ADR and also good practices in the member states.

Development of ADR regulations within the EU

In the last decade, ADR has become an established part of the dispute resolution in construction and in general commercial dispute resolution in the UK, following its birth and rapid growth in the United States. Compared to other member states, the UK is the first in the EU to institutionalize ADR with respect to both enactment of regulations and the wide acceptance in practice (Cairns 2005). Nesic (2002) explains, in her discussion of the status of ADR in UK, that the construction industry in the UK is the largest single user of ADR (mediation), followed by other industries. The greatest determining factor in the successful deployment of ADR in the UK has been the robust government policies and regulations that promote ADR, such as the Housing Grants, Construction and Regeneration Act in1996 (which imposed the statutory adjudication for the resolution of construction disputes), the Woolf Reforms in Civil Procedure Rules in1998 (which promote the use of ADR before commencing proceedings) and the ADR Pledge in 2001 committing all UK Government Departments and agencies to settle disputes by ADR. These regulations resulted in a substantial reduction in domestic arbitration and litigation, where the number of new proceedings issued in the Technology and Construction Court in 2004 dropped to 390, which is only 22% of the 1778 new proceedings in 1995 (Gaitskell 2005). In the same period, an increase is observed in the number of commercial and non-commercial ADR providers, who are an indispensable part of the system.

Following the rapid development of ADR in the UK, the EU also declared the deployment of ADR as a “political priority”. In April 2002, the European Commission prepared a consultation report, the Green Paper on Alternative Dispute Resolution in Civil and Commercial Law due to the increasing attention on and diversity of ADR practices in the member states.

Green Paper on ADR in civil and commercial law

The objective of the Green Paper was to initiate a broad-based consultation on the salient features of the ADR processes. This would allow the determination of the approach to be taken by the Commission in promoting ADR and the determination of European Community-wide rules, which will constitute a common base for the institutions that have been deployed and those that will be deployed in future. In this context, the Commission stated the role of ADR as offering an alternative to the problems associated with litigation, emphasizing the growing number of the cross-border disputes that bring forth the problem of the conflict of national laws and jurisdiction. In addition, it invited the member states to encourage the bodies responsible for out-of-court settlement to operate in a way that provides adequate procedural guarantees for the parties concerned. Academic studies are also encouraged as an important help for the public authorities in their task of monitoring and/or developing ADR. The paper was in the form of discussion topics raising a series of questions concerning the possible regulations about ADR processes. The responses were received from the governments of member states and also third countries, ADR providers, structures for training and information in ADR, academic circles, judges, bar associations, commercial companies and professional federations which helped the Commission to define the general lines of the policies and its role as the promoter of legislative and operational initiatives. This consultation resulted in the Proposal for a Directive in October 2004.

Proposal for a directive on certain aspects of the ADR process of mediation in civil and commercial matters

On 22 October 2004, the European Commission published a Proposal for a Directive seeking to facilitate access to dispute resolution by promoting the use of mediation, which is among the widely used methods of ADR. The Proposed Directive defines mediation in Article 2 as a process where two or more parties to a dispute are assisted by a third party to reach an agreement on the settlement of their dispute, regardless of whether the process is initiated by the parties, suggested or ordered by a court or prescribed by the law. As a result of the consultation made in Green Paper, the Directive comprises the base rules to be adopted by the member states for the implementation of mediation concerning the referral to mediation, ensuring the quality of mediation, the enforcement of the settlement agreements and suspension of limitation periods. In the explanatory memorandum 1.1.3 of the Directive, the Commission stresses the untapped potential that mediation holds as a dispute resolution method and as a means of providing access to justice for individuals and businesses as a quicker, simpler and more cost-efficient way to solve disputes. It also allows for taking into account a wider range of interests of the parties, with a greater chance of reaching an agreement which will be voluntarily respected, and which preserves an amicable and sustainable relationship between them. When agreed, the Directive will apply to all civil and commercial matters and to cross-border disputes, making provision that member states will bring into force laws, regulations and administrative provisions necessary to comply with the Directive by 1 September 2007. As a candidate state, Turkey also has to follow and adopt the EU Acquis in order to progress in the Accession Negotiations.

ADOPTION OF THE EU ACQUIS IN ADR

In July 1959, Turkey made its first application to join the then recently established European Economic Community. The ensuing negotiations resulted in the signature of the agreement creating an association between the Republic of Turkey and the European Economic Community (the "Ankara Agreement") on 12 September 1963. This agreement aimed at securing Turkey's full membership in the EEC through the establishment in three phases of a customs union that would serve as an instrument to bring about integration between the EEC and Turkey. On 1 January 1996, the Customs Union came into effect and shortly after, at the Helsinki European Council held on 10–11 December 1999, Turkey was officially recognized as a candidate state on an equal footing with the other candidate states. At the end of 2004, the Accession Negotiations between the EU and Turkey were formally started, initiating a formalized process whereby Turkey will be required to complete the adoption of the EU Acquis. Turkey administers its adoption of the EU Acquis according to a "National Programme", furnishing a road map for adaptation of the legislation and the institutional development for implementation. The adaptation of legislation for ADR is beyond the scope of this paper; however, the current Turkish legislation regarding ADR is overviewed below for the judiciary linkages of the institutional development process.

Adaptation of the legislation for ADR

In Turkish law, there is no specific act pertaining to ADR in the existing legislation. However, there are provisions of ADR in some acts and draft acts. Within the National Programme, an ADR act is being prepared by the Ministry of Justice.

Advocateship Act

There are two acts in the current legislation that include provisions on ADR in Turkish Law, one being the Code of Criminal Procedure that is out of the scope of this paper and the other statutory provision that supports ADR is in the Advocateship Act. The Article 35/A of the Advocateship Act suggests that if a client demands mediation, the attorney may invite the other party to mediation. If the parties reach an agreement at the end of mediation, the act provides that the parties and the attorneys will execute a written agreement disposing of the dispute, which is enforceable in the same manner as any other final judgment (Ozbek 2005).

The Draft Civil Procedural Code

The draft code adopts a structure that enables and encourages the out of court dispute mechanisms. Although there are no specific provisions for ADR in the context of court proceedings, the second part of Article 145 gives the judge the duty of encouraging the parties for negotiation or mediation in the pre-investigation stage. If the judge is convinced that the parties may reach a settlement, or on the demand of the parties, he can postpone the hearing to another date in order to enable the parties to resolve their dispute by negotiation or mediation. The Explanatory Memorandum of the Draft Civil Procedural Code recommends the promulgation of a separate act to be drafted for the regulation of ADR in the legislation concordant to the legislation of the Member States of EU.

The Draft Non-contentious Judiciary and Alternative Dispute Resolution Act

As a part of the Judiciary Reform, the Ministry of Justice is planning to prepare this act for the adoption of ADR methods in Turkish law as a means to resolve disputes effectively, fast and with a minimum cost, covering provisions pertaining to both the ADR in the context of court proceedings and the regulations for conventional ADR.

The Draft Code of the Foundation, Duties and Authorities of Mediation Boards

This draft code suggests the settling of private law disputes between administrative authorities and private parties by ADR before commencing proceedings. In this draft code, reference has been made to Recommendation (2001)9 of the Council of Europe Committee of Ministers on alternatives to litigation between administrative authorities and private parties.

These developments in Turkey are closely observed by the European Commission. In addition to Accession Negotiations, assessment reports are prepared by the experts of the European Commission for monitoring both the adaptation of the legislation and the institutional development process. The Directorate General for Justice and Home Affairs and the Directorate General for Enlargement of the European Commission have made annual visits and prepared three assessment reports on Turkey's progress in the adoption of the EU Acquis in legislation. In their last advisory visit in 2005, the experts reported that the draft acts pertaining to ADR are being prepared and that their progress should be monitored closely. The experts recommended the adaptation of legislation should be completed and the institutes and/or boards be structured not only for resolving disputes between the parties but also constituting the benchmark criteria in their field of study (The Functioning of the Judicial System in the Republic of Turkey: 44).

The deployment of ADR is an important target in Turkey's State Strategy and Action Plan for 2007–2013 Judiciary Report (2006: 60). According to the report, ADR mechanisms such as negotiation, mediation, dispute resolution boards and ombudsmen that enable resolving disputes without going through a long judicial process with high costs should be adopted in order to reduce the disputes waiting for proceedings. To realize this objective, it is reported that the necessary councils for mediation and dispute review boards specialized in sectors base should be constituted.

ADR in Turkish construction industry

The implementation of ADR can be realized more successfully if planned on a sectoral base, since this gives the opportunity to constitute the institutional development according to the technical, economic, social and cultural aspects of a sector in order to meet its special needs.

Although there are some ADR mechanisms defined for some other fields, there are no institutions established for the resolution of disputes with ADR in Turkish construction industry. The one exception is the High Technical Board, which acts only as an advisory board to give expert opinion on the disputes in public works, only to the public authorities on their request. The High Technical Board was founded within the Ministry of Public Works and Settlement with the mission of preparing the standard contract types, specifications and price analysis for public works and providing expert opinion on the draft codes, statutes, regulations as well as the disputes in public works. The referral to High Technical Board before litigation is not obligatory for the parties and only public authorities can refer a dispute to the Board. Contractors and other parties do not have this right by law. The decisions taken by the Board are not recognized by law and, therefore, public authorities often hesitate to implement a decision in favour of the other parties and proceed to litigation. In practice when the disputes are referred to litigation after a decision taken by the Board, judges often decide in accordance with the decision of the Board. Similarly, when a dispute is taken to litigation directly, judges often take the dispute to the Board themselves. This mechanism causes a waste of time and other resources in the public works. On the other hand, the members of the Board are designated by the Ministry and these members work as officials of the Ministry, which raises doubts on the impartiality of the decisions taken on the disputes in public works.

Besides lack of adequate mechanisms, the lack of knowledge, experience and trained human resources in the industry concerning ADR results in poor administration of disputes especially in public works and international projects.

PRESENT PROBLEMS OF TURKISH CONSTRUCTION INDUSTRY ASSOCIATED WITH DISPUTE RESOLUTION

The public construction works and international projects are the main are areas prone to problems associated with dispute resolution in Turkish construction industry.

Public construction works

The state is the largest employer and investor in the Turkish construction industry but, at the same time, public construction projects are amongst the worst administered. Construction projects are by nature very prone to disputes. Since a legal and institutional framework does not exist for ADR in public construction projects, disputes normally end up in litigation, which in turn translates into failure in meeting project goals, both with respect to budget and schedule. Projects delayed for decades or left unfinished are very common figures of the Turkish public construction works landscape and no doubt, among other factors, notoriously slow progress of litigation has its share in it. The problems associated with the High Technical Board and the judiciary constitutes barriers that can hinder the progress in a project for a very long time. Because of the lack of specialized courts for construction disputes (such as the Technology and Construction Court in the UK), the disputes are referred to experts, but the judges have difficulty in finding qualified experts which is another reason for dissatisfaction with the judicial system beside the extremely long process.

In a research conducted by Gunay (2001), Turkish contractors were asked about their dispute experiences with the public authorities. The chosen group for the research comprised the members of the Turkish Contractors Association and most of the members reported that they had or still have disputes that lasted for years. The average duration of the disputes mentioned in the research that were resolved by the courts was seven years and the average was five years in the case of arbitration. However, in the same research, it was revealed that in many cases, to avoid a bad reputation, Turkish contractors refrained from taking disputes in public projects to the court and preferred to release their rights in fear of compromising their place in the invitation list to public tenders. These show that the current system of resolving public project disputes may not be equitable for both sides and more importantly causes a waste of the public resources in Turkish construction industry.

The study of Gunay (2001) also reports that the application of legal procedures in order to resolve disputes is less appreciated by the contractors in the presence of alternatives. The contractors considered a resolution method to provide partial acceptance or mutual coverage of expenses much more convenient than going to court. The reasons were explained as the monetary and non-monetary losses due to extremely long legal process, the worry about the impartiality and the qualifications of the court experts, the worry that employer would have a negative attitude for future works and the fact that gains do not compensate the real expenses even if a trial is won at court.

These problems associated with the adversarial methods of dispute resolution reported by the Turkish contractors can be avoided by the implementation of ADR in the public works. As suggested by Rubin and Quintas (2003), the real time approach to disputes in ADR can prevent antagonistic relationships by resolving claims promptly, allowing the work to proceed while claims are being considered. A dispute review board (DRB), for example, is established at the start of a project and is kept informed of the job's progress and of potential areas of dispute. In this way, if a dispute arises, DRB is already conversant with the background facts. This provides a first-hand knowledge on the issues in question and the consideration of disputes by knowledgeable industry professionals familiar with the often complex and technical issues that invariably arise during construction. In most ADR models, parties themselves identify either a person or a panel who will be responsible for examining project claims and to apply their knowledge to reach solutions based on the realities of the construction process either by issuing binding determinations, proposing viable solutions, or facilitating settlement, instead of applying the strict letter-of-the-law removed from its relevant context. On the other hand, Rubin and Quintas (2003) points to the biases, statutory constraints and policy considerations of the public authorities as factors affecting the dispute resolution process in public works and often diminishing some of the advantages that ADR has to offer. Therefore, the challenging next step in mainstreaming the use of ADR is to develop a model addressing the special concerns of public employers as well as the other actors in the industry.

International projects

International projects are another aspect where the institutional development of ADR is needed. In Turkey, expensive public construction projects tendered by a range of public authorities are often financed by international credit agencies that require the use of international standard contract forms with ADR provisions. These projects are usually contracted to multinational construction firms where the public authorities usually find themselves in poor administration of disputes that arise during the project because of their limited knowledge and experience in ADR procedures. On the other hand, Turkish contractors working abroad complain that they have difficulty finding human resources expert in ADR processes. These indicate the need for an institution giving consultancy, professional education and training on ADR in the Turkish construction industry.

THE FUNDAMENTAL CRITERIA SUGGESTED FOR THE INSTITUTIONAL DEVELOPMENT OF ADR IN TURKISH CONSTRUCTION INDUSTRY

The deployment of adequate ADR mechanisms is expected to result in more cost-effective and swifter solutions for disputes in the Turkish construction industry, and to prevent waste of resources, especially in the public works. In order to achieve this, there are legislative and institutional pre-requisites. The legislative prerequisites to put ADR to work in Turkish construction industry are beyond this paper’s purview and may vary, depending on the adopted approach, from promulgating a full-fledged ADR Act, to merely incorporating an ADR clause in the standard form of contracts used in public works. This chapter discusses the institutional pre-requisites.

Considering the problems of Turkish construction industry associated with dispute resolution, the obstacles and insufficiencies of the current mechanism and the requirements of the European Commission, a set of fundamental criteria is suggested for the institutional development of ADR in Turkish construction industry. In formulating these criteria, Esman’s (1972) conceptual framework is used. This framework suggests that the essential elements of institution building are the characteristics of the institute itself, its linkages with its environment and the actual transactions or exchanges that take place between it and its environment (Figure 1).

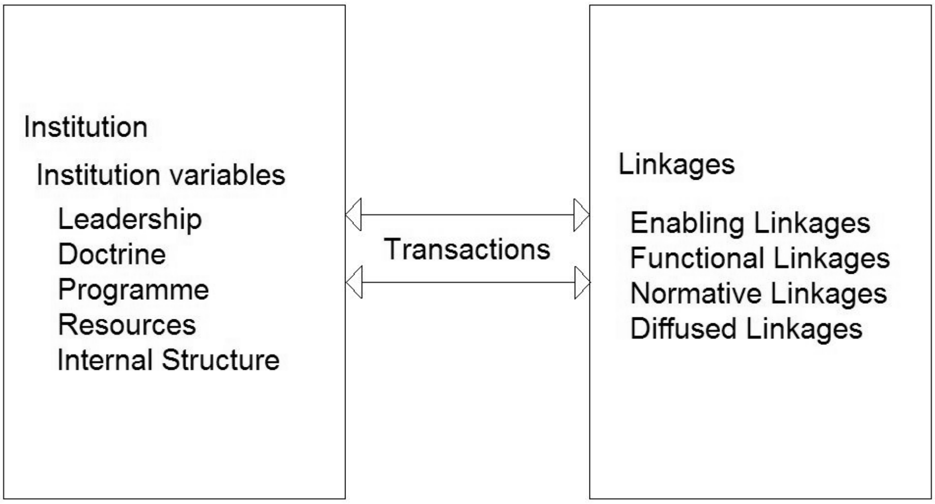


Figure 1: Esman's conceptual framework – 'the institution-building universe'

According to this framework, the major factors affecting the institution are its leadership, the doctrine or style and values that it adopts, the programme of work, the quantity and quality of resources available to it, and the appropriateness of its internal structure to the task and to the culture of the industry. Linkages describe the relationships between the institution and its environment. Enabling linkages establish its legality, purpose and resources, functional linkages establish its collaboration with complementary or competing institutions, which directly help in the achievement of objectives, normative linkages are the lesser relationships with other organizations of some common interest and diffused linkages are the relationships with external people or groups, which lend credibility or acceptability.

Institution

The institution should be specialized in construction ADR and responsible for all activities related to the development and implementation of ADR in Turkish construction industry.

Leadership

The institution should be developed in a way independent of direct government intervention in its internal functioning, autonomous itself or as part of an autonomous body like universities or professional federations.

Doctrine

- The values adopted should be in accordance with the values of European Commission, which are revealed in its Green Paper, The Proposed Directive and the Code of Conduct for Mediators.
- Impartiality: confidence is one of the most important issues in the adoption and the proper functioning of such an institute in the industry especially when dealing with disputes in public projects.
- Research-based: the task of development and the monitoring of ADR in the industry relies on a research based approach as suggested in European Commission's Green Paper.

- International recognition: sustainable development requires the collaboration with similar institutions in other countries.
- Client focused: quality control mechanisms should be constituted concerning the services given.

Programme

- Establishment of the Codes of Conduct for ADR procedures in the Turkish construction industry.
- Determination of referral and settlement processes and preparation of related documents.
- Training of the neutrals.
- Accreditation of the neutrals.
- Promotion of development of ADR in the industry.

Resources

At the initiation stage, the institution should be sponsored by government funds. The functioning should be arranged targeting the creation of own resources.

Internal structure

Task groups should be established for administration, research, training and accreditation.

Enabling linkages: linkages with the government

- Government policies should be constituted for the institutional development of ADR in sectors base.
- Legitimacy and relations with the other government agencies should be stated and specified in regulations.
- Funds should be supplied according to the programme of the Institute.
- Education should be given to relevant professional groups in the judiciary and in related government agencies.

Functional linkages: linkages with the judiciary

- Courts should be given the authority to invite the parties to use ADR in construction disputes.
- It should be ensured that a settlement agreement reached as a result of an ADR process can be confirmed by a court or public authority that renders the agreement enforceable in a similar manner as a court judgment.
- The disclosure of the information or evidence regarding to the course of ADR should not be ordered by the judicial authorities and should be treated as inadmissible.
- The running of limitation periods regarding the dispute that is the subject matter of the ADR process should be suspended during the ADR process.

Normative linkages: linkages with other organizations
The institution should work in collaboration with related EU agencies and other institutions in member states. It should be the member of established networks for international recognition and sustainable development. It should also work in collaboration with the professional associations in Turkish construction industry for the successful institutional development of ADR in the industry.

Diffused linkages: linkages with external groups
The institution should be supported by the prominent people and groups of the industry at the initiation stage.

CONCLUSION

The problem of unfinished public projects, the waste of resources due to poor dispute resolution practices and the need for adequate mechanisms have identified dispute resolution as a key area requiring improvement in Turkish construction industry. Despite the need for more cost-effective and swifter dispute resolution methods especially in the public works and international projects, lack of institutional development has evidently been hindering the acceptance of ADR in the industry. The practices of ADR development in other countries and the debate in the literature show that adequate legislation and institutional development are the pre-requisites for the adoption of such new methods. In the last five years, ADR is announced as a political priority by the European Commission, followed by the presentation of the Green Paper and the Proposal for a Directive and efforts are made by the member states for the adaptation of legislation and the institutional development of ADR in compliance with these reports. Being a candidate state, putting ADR to work is one of Turkey's tasks to be fulfilled in the process of adoption of the EU Acquis; more resolute policies are needed however for timely planning and implementation taking in account its urgency for the Turkish construction industry, especially in public and international projects.

Considering the problems of the Turkish construction industry associated with dispute resolution, the obstacles and insufficiencies posed by the current situation and the requirements of the European Commission as discussed throughout the paper, a set of fundamental criteria is suggested for the institutional development of ADR in the Turkish construction industry, concerning the leadership, doctrine, programme, resources, internal structure and the linkages with the government, the judiciary, other organizations and external groups. Development and implementation of a model as based on the fundamental criteria suggested in this paper is needed for the application and promotion of ADR, and should be tackled in future research as it is deemed to bear actual significance for unfettered development of the Turkish construction industry.

REFERENCES

Adriaanse, J (2005) *Construction contract law: The essentials.* New York: Palgrave MacMillan.

Ashworth, A (2005) *Contractual procedures in construction industry.* 4ed. London: Pearson Longman.

Björnberg, K and Cranston, R (2005) *The Functioning of the Judicial System in the Republic of Turkey, Report of an Advisory Visit*. Brussels: European Commission.

Brooker, P and Lavers, A (1997) Perceptions of Alternative Dispute Resolution as constraints upon its use in the UK construction industry. *Construction Management and Economics*, **15**, 519–26.

Buyck, B (1991) *The Bank's use of technical assistance for institutional development, World Bank Working Paper Nr.578*. Washington DC: World Bank

Cairns, D J A (2005) Mediating International Commercial Disputes: Differences in US and European Approaches. *Dispute Resolution Journal*, Aug–Oct.

Carmichael, D (2002) *Disputes and international projects.* The Netherlands: Swets & Zeitlinger.

Cheung, S (2006) Mandatory use of ADR in construction – A fundamental change from voluntary participation. *Journal of Professional Issues in Engineering Education and Practice*, **July**, 224.

Cheung, S, Suen, H and Lam, T (2002) Fundamentals of Alternative Dispute Resolution processes in construction. *Journal of Construction Engineering and Management,* **128**(5), 409–17.

Commission of the European Communities (2002) *Green paper on ADR in civil and commercial law,* Brussels. Available online: http://eur-lex.europa.eu/LexUriServ/site/en/com/2002/com2002_0196en01.pdf

Commission of the European Communities (2004) *Proposal for a directive on certain aspects of the ADR process of mediation in civil and commercial matters*, Brussels. Available online: http://eur-lex.europa.eu/LexUriServ/site/en/com/2004/com2004_0718en01.pdf

Esman, M J (1972) The elements of institution-building. *In:* J. Eaton (Ed.) *Institution-building and development.* London: Sage Publications.

Gaitskell, R (2005) Current Trends in Dispute Resolution. *Arbitration Journal,* **Nov**., 288–99.

Gunay, G (2001) *Dispute creation and resolution mechanisms of the Turkish construction sector in public projects.* Ankara: Turkish Contractors Association.

Kaming, P F, Olomolaiye, P O, Corbett, P and Harris, F C (1994) A framework for the strategic development of the construction industries in developing countries. *Building Research and Information*, **22**(6).

McDermott, P and Quinn, B (1995) Latham Causes Conflict: Institutional Development in the UK construction industry. *Journal of Construction Procurement*, **1**(2), 150–64.

Nesic, M (2001) Mediation – on the rise in the United Kingdom. *Bond Law Review*, **13**(2).

Ozbek, M (2005) *Report on Alternative Dispute Resolution within the better access to justice project*, Ankara. Available online: http://www.ankarabarosu.org.tr/download/adr/justiceproject.doc

Prime Ministry State Planning Organization (2006) *Turkey's State Strategy and Action Plan for 2007-2013 Judiciary Report.* Available online: http://plan9.dpt.gov.tr/oik20_1_adalet/adalet-9p-oik.pdf

Rubin, R A and Quintas, B V (2003) Alternative Dispute Resolution in US public works: Proposed model. *Journal of Professional Issues in Engineering Education and Practice,* **129**(2), 80–3.

AN EXAMINATION OF THE PERFORMANCE OF STATUTORY ADJUDICATION IN NEW SOUTH WALES AFTER 2000 ADJUDICATION DETERMINATIONS

Michael C. Brand[1] and Thomas E. Uher

Faculty of the Built Environment, The University of New South Wales, Sydney, 2052, Australia

The Building and Construction Industry Security of Payment Act 1999 (NSW) (the NSW Act) is a unique form of statutory regulation for the building and construction industry, which gives virtually all industry participants a statutory right to, and a means of recovering, payments for work done under a construction contract. The research aim is to examine current trends in adjudication applications and determinations under the Act. The data used were those collected by the NSW Department of Commerce as part of a regular reporting regime, which covers the period from 3 March 2003 to 30 June 2006. The research reveals that the adjudication process of payment claim disputes under the NSW Act continues to grow in popularity, and the level of knowledge and awareness of the NSW Act among those working in the construction industry appears to be increasing. Claimants making small payment claims are generally more successful at adjudication than those making large claims. The NSW Act has not yet succeeded in discouraging parties from engaging in the practice of either unduly inflating or undervaluing progress payments. While adjudication provides claimants with a relatively inexpensive means of determining disputes as to payment, further research is needed in order to verify or otherwise the real cost-benefits of the adjudication process in NSW.

Keywords: adjudication, dispute resolution, performance, security of payment.

INTRODUCTION

This paper reports on an ongoing research project being undertaken by the authors into the performance of the Building and Construction Industry Security of Payment Act 1999 (NSW) (hereafter referred to as the 'NSW Act').

The NSW Act commenced in March 2000 and was introduced as part of the New South Wales Government's policy to eradicate the practice of developers and contractors arbitrarily delaying payment to subcontractors and suppliers in the NSW building and construction industry (Iemma 1999). The NSW Act is the first comprehensive legislative scheme to be introduced in Australia to provide, *inter alia*, contractors, subcontractors and building professionals with a statutory right to, and a procedure to recover, progress payments. While it embraces the philosophy of rapid 'statutory adjudication' of payment claim disputes introduced in the UK in the form of the Housing Grants, Construction and Regeneration Act 1996, the NSW Act is substantially different in its structure and operation from its UK counterpart. Similar legislative schemes to that operating in NSW and the UK have since been introduced

[1] michaelb@fbe.unsw.edu.au

in Victoria, Queensland, Western Australia, New Zealand and Singapore, with Malaysia planning to introduce its own legislation in 2007.

'Statutory adjudication' is a process defined in the Act of referring a payment claim dispute to an independent third party known as 'adjudicator'. Whenever a claimant endorses a payment claim as a claim made under the Act, the claimant may elect to have the payment claim adjudicated upon if the respondent withholds payment. The mechanism set out under the Act that leads to an adjudication of a payment claim requires: the claimant to serve a payment claim endorsed under the Act; the respondent to serve a payment schedule indicating the amount of progress payment (if any) that the respondent is prepared to pay and the reasons for withholding payment; the lodgement of an adjudication application by the claimant with an Authorized Nominating Authority (ANA); and the submission of the adjudication response by the respondent within the strict time limits imposed by the Act.

This paper will only be concerned with the NSW Act. As a consequence of a formal review undertaken at the end of the Act's first three years of operation, the Act was significantly amended by the Building and Construction Industry Amendment Act 2002 (NSW) (hereafter referred to as the 'Amendment Act') (Davenport 2003 and 2004). Accordingly, the 'NSW Act' referred to here is the NSW Act as amended.

The aim of the research is to examine the trends in adjudication determinations made under the NSW Act between March 2003 and June 2006. In particular, the paper will attempt to ascertain whether or not the amended Act introduced in March 2003 improved access of claimant organizations to adjudication of payment claims, subcontractors in particular. To that end the trend in the number of adjudication applications and adjudication determinations as well as the rate of success of claimants at adjudications made will be examined. Apart from improving security of payment, the Act also intends to provide a fast and inexpensive mechanism for resolving payment claims disputes. In this regard, this paper will attempt to ascertain a trend in the cost of adjudication.

Given that other Australian jurisdictions have adopted or are about to adopt a similar legislative framework to that in place in NSW, the emerging trends in connection with use of the Act in NSW identified in this research are expected to assist legislators in developing appropriate security of payment schemes or fine tuning those schemes already in use.

SECURITY OF PAYMENT

In the context of this paper, 'security of payment' is a generic term used to describe (NSW Government 1996: 41):

> [T]he entitlement of contractors, subcontractors, consultants or suppliers in the contractual chain to receive payment due under the terms of their contract from the party higher in the chain.

Thus, the security of payment problem refers to (Commonwealth of Australia 2002: 7):

> [The] consistent failure in the building and construction industry to ensure that participants are paid in full and on time for the work they have done, even though they have a contractual right to be paid.

Although the extent of the security of payment problem is unknown, it is generally accepted that it has been an ongoing issue for those who carry out construction work, or supply related goods and services under a construction contract (Commonwealth of Australia 2002).

In sum, the security of payment problem is the result of the practice by principals and contractors in the construction industry of unduly delaying and devaluing progress payments owed to subcontractors for work done under construction contracts. The tactic of principals and contractors in delaying payments or unduly reducing the value of payments is largely designed to enhance their positive cash flow at the expense of subcontractors (Brand and Uher 2004).

The security of payment problem has long been a major source of commercial hardship for those operating in the construction industry, particularly for the many small and often undercapitalized firms, which operate at or near the bottom of the contractual chain (Iemma 1999). It is suggested that, but for the systemically poor payment behaviour of principals and contractors, the problems of commercial hardship and failure among small firms in the construction industry would largely be avoided. Furthermore, one must not overlook the potential for the unnecessary generation of societal problems, such as unemployment and welfare dependence, which often accompanies commercial hardship and failure (Commonwealth of Australia 2002). Thus, any debate concerning security of payment is one that must inevitably deal with the issues of social security.

The next section of the paper describes the research method adopted in this study followed by a synthesis and analysis of the data. Lastly, conclusive remarks are presented.

RESEARCH METHOD

The operation of the security of payment legislation in NSW is facilitated by Authorized Nominating Authorities (ANAs). In total, nine such ANAs are registered in NSW. Their function is to accept adjudication applications, appoint adjudicators and issue upon request an adjudication certificate. Furthermore, each ANA is required by the NSW Department of Commerce (hereafter referred to as the Department) to report regularly on a variety of matters relating to adjudication applications and determinations made in NSW. Reporting is required by the Department with a view of allowing it to ‘better monitor trends in adjudication’ (NSW Department of Commerce, 2004: 6). Data used for this research are the data collected by the Department as part of the aforementioned reporting regime. The data used cover the period from 3 March 2003 (i.e. the date of commencement of the Amendment Act) to 30 June 2006. The data are in the form of tables and figures and are presented in this paper as Tables 1–6 and Figure 1.

Since the data collected by the Department are not aggregated according to the participating ANAs and the type of claimant and respondent firms, the authors were unable to assess the performance of individual ANAs and determine trends in the number of the adjudication applications made by different types of claimant and respondent firms.

The format of the data has ruled out a statistical analysis. Instead the authors attempted to subjectively interpret trends emerging from the data and relate them to the findings derived by the authors in their previous research into the performance of the adjudication process in NSW.

ADJUDICATION APPLICATIONS

As at 30 June 2006, a total of 2698 completed adjudication applications have been lodged with ANAs in NSW.

It is worth noting in Table 1 that since the commencement of the Amendment Act in 2003, the number of adjudication applications increased sharply, and despite a period of levelling off in 2005, the indication is that it continues to rise. The total value claimed under all completed adjudication applications is in the order of AU$1.79 billion (≈ US$1.41 billion). As at 30 June 2006, the highest and lowest claimed amount is AU$93.9 million and AU$224 respectively.

Table 1: Number of adjudication applications

Period	No. of applications
First three years (2000–2002)	116
Year 2003	593
Year 2004	746
Year 2005	734
Year 2006 (up to 30 June 2006)	509

Of the total number of completed adjudication applications lodged with ANAs 74.1% have been determined. At the time of writing, about 2% of all completed adjudication applications were pending determination and about 22% have been 'completed but not determined'. The Department does not explain the status of the remaining less than 2% of adjudication applications lodged.

Adjudication applications that are classified by the Department as 'completed but not determined' are those that are neither determined nor pending determination. This means that while such adjudication applications were made to ANAs, for reasons such as invalidity or withdrawal of applications or settlement of a dispute by the parties, no determinations were made for those applications.

The reasons for, and corresponding distribution of, 'completed but not determined' adjudication applications as at 30 June 2006 are given in Table 2.

Table 2: Reasons for 'completed but not determined' applications

Reasons	Number (% of total)
Withdrawn by claimant	96 (16.0%)
Parties settled and application withdrawn	224 (37.3%)
Invalid application under the NSW Act	271 (45.2%)
ANA/Adjudicator out of time	9 (1.5%)
Total	600 (100%)

Table 2 shows that the rate of withdrawal of adjudication applications once lodged with an ANA is relatively low. However, the Department does not explain the reason for such withdrawals. Table 2 also shows that ANAs appear to be administering adjudication applications promptly and that adjudicators are adhering to the time constraints placed upon them by the NSW Act in accepting adjudication applications and delivering determinations. For clarity, under the NSW Act an adjudicator is required to complete an adjudication determination within 10 business days from accepting nomination, unless the parties agree to grant the adjudicator extra time.

An interesting trend that emerges is that a significant number of disputes as to payment in the 'completed but not determined' category of adjudication applications are settled by the parties after lodgement of an adjudication application but before the application is determined by the adjudicator. Thus, the above data provide *prima facie* evidence that the adjudication process is actively encouraging parties to resolve disputes as to payment between themselves without the need for third party interference. Furthermore, since claimants often use the adjudication process soon after a payment claim dispute arises, it is arguable that the adjudication process is a catalyst for early dispute resolution between parties in the construction industry.

Almost half of all ‘completed but not determined’ applications are invalid under the NSW Act; this equates to about 10% of all completed adjudication applications. While no reasons are given as to why the applications are invalid under the NSW Act, it is likely that their invalidity is related to adjudication applications not meeting the requirements of the NSW Act when closely scrutinized by adjudicators in the course of making an adjudication determination. Brand and Uher (2004) reported a relatively low working knowledge of the NSW Act among particularly smaller subcontracting firms. This may help to explain the reason for invalidity of some adjudication applications. Nevertheless, it is apparent that a large majority of claimants have the requisite working knowledge of the NSW Act and are able to make valid adjudication applications.

Provision of payment schedules

The Department classifies adjudication applications as: (a) ‘standard’; (b) ‘optional with schedule’; and (c) ‘optional without schedule’ (NSW Department of Commerce 2004).

The ‘standard’ application is one where the respondent provides, in response to a payment claim, an initial payment schedule to the claimant in accordance with the Act and the claimant either rejects the scheduled amount or the respondent does not pay the claimant in accordance with the payment schedule on or before the due date for payment. The ‘optional with schedule’ application is one where the respondent fails to provide an initial payment schedule to the claimant in response to a payment claim but does so once the claimant notifies the respondent of its intention to apply for adjudication under s.17(2) of the Act. The ‘optional without schedule’ application is one where the respondent fails to provide an initial payment schedule to the claimant and also fails to provide a payment schedule after the claimant notifies the respondent of its intention to apply for adjudication under s.17(2) of the Act. It should be noted that s.17(2) of the NSW Act requires a claimant to gives a respondent two chances to provide a payment schedule before the claimant is permitted to lodge an adjudication application.

The frequency of submission of payment schedules as at 30 June 2006 under the three abovementioned classifications is given in Table 3.

Table 3: Frequency of submission of payment schedules by classification

Classification	Number (% of total)
Standard	1442 (53.5%)
Optional with payment schedule	217 (8.0%)
Optional without payment schedule	1038 (38.5%)
Unknown status	1 (0.0%)
Total	2698 (100%)

Table 3 shows that in about 60% of cases respondents provide a payment schedule in response to payment claims. Of these respondents about 85% provide an initial payment schedule to a payment claim. The remaining 15% of respondents provide a payment schedule after being notified under s.17(2) of the Act.

Surprisingly, about 40% of respondents do not provide a payment schedule in response to a payment claim. It should be noted that in the absence of a payment schedule, the claimed amount becomes a statutory debt and the respondent is not permitted to lodge an adjudication response to the claimant's adjudication application. A reason reported by the Department (NSW Department of Commerce 2004: 8) for the high proportion of respondents not submitting a payment schedule is that '[respondents] invariably ignore payment claims in order to delay or escape payment'. In consideration of the consequences under the NSW Act for not providing a payment schedule, it is reasonable to conclude that it may also be a result of respondents not understanding the timeframes and procedures set out in the NSW Act with regard to the submission of a payment schedule. However, if this is to be considered a significant reason for the high proportion of respondents that do not provide a payment schedule, then the result is anything but unexpected given that the Act has been in operation for over six years.

ADJUDICATION DETERMINATIONS

The Department reports that as at 30 June 2006, in excess of 2000 adjudication applications of payment claim disputes have been determined in NSW. The total value of determined applications is AU$1.53 billion (≈ US$1.20 billion). During the period, the highest and lowest adjudicated amount is reported as AU$93.9 million and AU$880 respectively.

Since adjudication applications are only concerned with payment claim disputes, it will be of interest to examine in the following sections of this paper the distribution of amounts claimed in payment claims and amounts of such payment claims actually determined by adjudicators.

Payment claims

The distribution of amounts of payment claims sought by claimants in adjudication applications that were determined by adjudicators is shown in Figure 1.

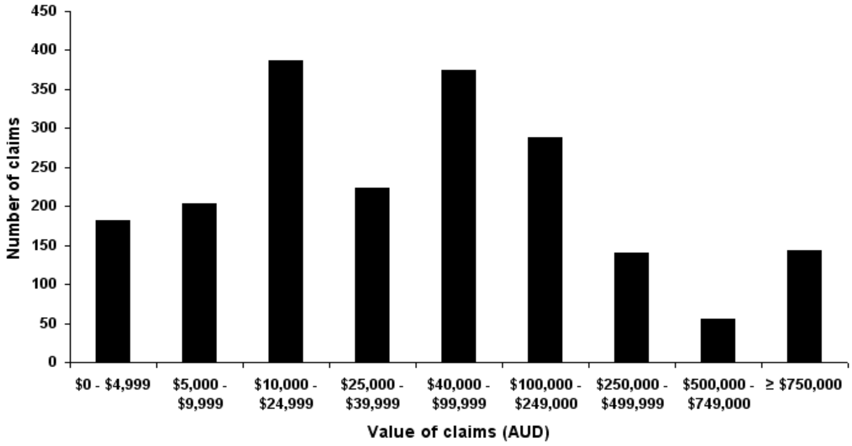


Figure 1: Distribution of amounts of payment claims as at 30 June 2006

Figure 1 shows that about half of all payment claims determined were less than $40 000 in value while about 17% were $250 000 or greater. The most frequently determined payment claims were those of the amount between $10 000–$24 000 and $40 000–$99 000.

However, the Department's data do not identify the type and size of claimants within each range of claims. Brand and Uher (2004) reported that around two-thirds of adjudication applications in NSW are being made by subcontractors. They expected that owing to the smaller size of their contracts, subcontractors' payment claims would be smaller than those made by contractors (Uher and Brand 2005). However, they found that amounts of payment claims made by subcontractors and contractors that proceed to adjudication under the NSW Act are not significantly different from each other. They explained that this is likely due to the fact that contractors' claims against clients are generally made for individual progress payment claims while subcontractors more commonly make claims for the sum of unpaid progress claims.

Level of success of claimants at adjudication

The distribution of outcomes measured as a percentage of claims determined under each adjudication application classification as at 30 June 2006 is shown in Table 4.

Table 4: Distribution of outcomes measured as a percentage of claim determined

Adjudicated amount as % of claimed amount	Standard adjudication	Optional with payment schedule	Optional without payment schedule
100%	317 (28.5%)	80 (44.2%)	461 (67.1%)
80%–99%	238 (21.4%)	35 (19.3%)	103 (15.0%)
60%–79%	110 (9.9%)	17 (9.4%)	33 (4.8%)
40%–59%	112 (10.1%)	10 (5.5%)	11 (1.6%)
20%–39%	105 (9.5%)	9 (5.0%)	14 (2.0%)
1%–19%	85 (7.7%)	10 (5.5%)	12 (1.7%)
0%	144 (13.0)	20 (11.0%)	53 (7.7%)
Total	1111 (100%)	181 (100%)	687 (100%)

A factor to be considered in determining the level of success of claimants at adjudication is the frequency of favourable outcomes measured in terms of the adjudicated amount. Table 4 shows that, on average, claimants were awarded 50% or more of the claimed amount in about 74% of reported adjudication determinations. On average, claimants were awarded the full amount claimed in about 43% of reported adjudication determinations. Only in about 11% of cases were claimants awarded $nil. The data show that claimants achieve the best outcome in adjudication, i.e. they secure the entire claimed amount, when respondents fail to provide a payment schedule. Conversely, claimants' rate of success at adjudication declines sharply when respondents provide a payment schedule.

Trends are also beginning to emerge in relation to the success of claimants at adjudication across a range of payment claim values. Table 5 shows the average claimed, scheduled and adjudicated amount across a range of payment claim values as at 30 June 2006.

Table 5: Average claimed, scheduled and adjudicated amount

Range of claims determined (AU$)	Av. claimed (AU$)	Av. scheduled (AU$) (% of av. claimed)	Av. determined (AU$) (% of av. claimed)
< $5000	$2920	$299 (10.2%)	$2604 (89.2%)
$5000–$9999	$7318	$407 (5.6%)	$6582 (89.9%)
$10 000–$24 999	$16 688	$975 (5.8%)	$13 300 (79.7%)
$25 000–$39 999	$31 968	$2866 (9.0%)	$25 816 (80.8%)
$40 000–$99 999	$63 634	$2545 (4.0%)	$44 714 (70.3%)
$100 000–$249 999	$159 381	$15 557 (9.8%)	$99 446 (62.4%)
$250 000–$499 999	$350 963	$7 323 (2.1%)	$256 112 (73.0%)
$500 000–$749 999	$620 672	$20 407 (3.3%)	$327 014 (52.7%)
≥ $750 000	$9 456 585	$848 247 (9.0%)	$2 291 368 (24.2%)

What emerges from Table 5 is that across the entire range of payment claims determined in adjudication respondents are only prepared to pay up to 10% of the claimed amount. Is it because claimants' payment claims are inflated or exaggerated, or does the above finding indicate that respondents are engaging in gross undervaluation of payment claims? The analysis of data in Table 5 with regard to the amount claimed and the amount adjudicated provides a possible answer.

The data show that the average adjudicated amount is about 70% of the average claimed amount across the whole range of claims determined. This clearly indicates that claimants are successful in adjudication, particularly those making smaller (in $ value terms) payment claims. For example, for payment claims less than $5000 in value claimants recover on average around 89% of the claimed amount. However, the claimants' rate of success in adjudication declines sharply with an increase in the amount of money claimed. For example, the adjudicated amount of large claims over $750 000 in value declines to only 24.2% of the claim.

Although the Department's data do not identify specific reasons for scheduled and adjudicated amounts being less than claimed amounts, the analysis of the data in Table 5 suggests that there can be no doubt that payment claims are inflated, particularly large payment claims.

However, to what extent small payment claims are inflated is unclear. Brand and Uher (2004) reported that although small size subcontractors' working knowledge of the Act and its requirements is only superficial, in making payment claims and in lodging adjudication applications they do not actively seek assistance of lawyers or claim consultants. It may well be that their non-compliance with some of the requirements of the Act, for example, in fully substantiating payment claims, may be the reason for the reduction in the value of small payment claims in adjudication. Whether or not such non-compliance is responsible for the reduction of the entire 11% for payment claims of less than $5000 in value, is again unclear. Considering that respondents generally do not defend small payment claims by employing lawyers or claim consultants in preparing payment schedules and adjudication responses (Uher and Brand 2005), respondents may not regard overvaluation of small payment claims, if any, as a major issue of concern.

Claimants making large payment claims are almost always assisted by lawyers or claim consultants (Brand and Uher 2004), yet such claims result in only 24.2% return to claimants in adjudication (for claims in excess of $750 000). While the presence of such experts in substantiating large payment claims does not rule out the possibility of non-compliance with some of the requirements of the Act, which may be a reason for a reduction in the value of payment claims in adjudication, nevertheless the relatively small return to claimants appears to support the view that large payment claims are inflated.

While the Act has over its first six years of operation in NSW markedly improved security of payment, it has thus far been ineffective in preventing claimants from inflating and respondents from undervaluing payment claims.

COST OF ADJUDICATION

One of the salient objectives of the adjudication process is to provide claimants with a relatively inexpensive method of having disputes as to payment determined by a neutral adjudicator. The distribution of the average total direct fees for all adjudication determinations (i.e. the fees of the ANA and the fees and expenses of the adjudicator) as at 30 June 2006 is given in Table 6.

Table 6: Total direct fees for all adjudication determinations

Range of claims determined (AU$)	**Av. claimed (AU$)**	**Av. total fees (AU$) (% of av. claimed)**
< $5,000	$2920	$544 (18.6%)
$5000–$9999	$7318	$829 (11.3%)
$10 000–$24 999	$16 688	$1497 (9.0%)
$25 000–$39 999	$31 968	$2082 (6.5%)
$40 000–$99 999	$63 634	$2630 (4.1%)
$100 000–$249 999	$159 381	$4391 (2.8%)
$250 000–$499 999	$350 963	$9050 (2.6%)
$500 000–$749 999	$620 672	$6660 (1.1%)
≥ $750 000	$9 456 585	$15 660 (0.2%)

The Department's data do not explain under what circumstances claimants are required to pay adjudication fees. Uher and Brand (2005) reported that when adjudicators award a nil amount of a payment claim, claimants are generally required to pay 100% of the adjudication fee. However, when adjudicators award less than the full amount of payment claim to claimants, the amount of the adjudication fee that claimants are required to pay may vary from nil to less than 100%. This is because under the NSW Act, adjudicators are able, at their discretion, to determine the proportion of the fee each party is required to pay. Some adjudicators require respondents to pay the full amount of the adjudication fee even if claimants are awarded only around 50% of a payment claim. Their argument is that respondents have unreasonably withheld a substantial amount of progress payment and have caused claimants to proceed to adjudication. Some other adjudicators apportion the adjudication fee evenly or unevenly between the parties in line with the adjudicated amount.

While the amounts of total direct fees for adjudication are relatively modest, Table 6 also shows there is an inverse relationship between the amount claimed and the total adjudication fee when expressed as a percentage of the amount claimed. It is interesting to note that although claimants making small payment claims are awarded on average at least 89% of the claimed amount, they may be required to pay the adjudication fee of up to 18.6% of the claimed amount, if they are not totally successful in adjudication. Conversely, the amount of adjudication fee that claimants of large payment claims may be required to pay when not fully successful in adjudication is very small indeed when expressed as a percentage of the claimed amount.

The direct costs of adjudication shown in Table 6 appear modest enough to conclude that adjudication provides claimants with a relatively inexpensive means by which they are able to have disputes as to payment determined by an independent third party. However, while the direct costs of adjudication do not appear to be a problematic issue at this point, meeting the indirect costs of adjudication (i.e. the cost of lawyers' and other consultants' fees) may pose more of a challenge to prospective claimants and respondents. According to Brand and Uher (2004), the cost of preparing adjudication applications and adjudication responses by lawyers and other consultants is significant. They reported that the direct cost to the claimant of preparing a simple payment claim for the amount of $7000 would be around $1000. However, with lawyers involved in preparing an adjudication application for the claimant and an adjudication response for the respondent, the overall cost of adjudication may be as high as $20 000. Thus, it may be said that the intervention of lawyers and other consultants in preparing submissions, particularly in relation to small claims, offsets the NSW Act's objective of providing claimants with a relative inexpensive method of having disputes as to payment determined by a neutral third party. However, if large claims are said to be inflated, and include for example unauthorized variations and delays costs, the presence of lawyers may be necessary to protect respondents from inflated or ambit claims. Legal costs in such circumstances may well be justified. Notwithstanding that such costs may be incurred regardless of the type of dispute resolution process employed, further research is necessary to verify the real cost benefits (if any) of adjudication under the NSW Act.

CONCLUSION

The foregoing discussion on the emerging trends in adjudication in NSW highlights the rapid growth in the number of adjudication applications made under the amended Act. The amended NSW Act has now been in operation over four years and the increasing number of adjudication applications may indicate the growing knowledge and awareness of the NSW Act among the parties working in the construction industry as well as the success of the changes made to the original Act, which, among other things, improved the method of selecting adjudicators and provided for the issue of an adjudication certificate, which when filed in a court, amounted to a judgment for a debt. Of particular interest is the finding that subcontractors, the party at which the Act was primarily targeted, access the Act and its provisions more frequently than contractors.

Claimants' knowledge of the NSW Act appears at present superior to that of respondents. This is evidenced on the one hand by only a small number of invalid adjudication applications lodged by claimants with ANAs and by a relatively low frequency of submission of payment schedules by respondents on the other hand. The fact that the provisions of the Act are initiated by claimants, who have sufficient time to prepare a claim in accordance with the requirements of the Act, may explain why claimants appear to have better understanding of the Act than respondents.

In general, it was found that claimants are highly successful at adjudication measured in terms of the proportion of the claimed amount they are awarded by adjudicators, with claimants making small payment claims being generally more successful than those making large claims. This seems to vindicate the introduction of the Act as a means of improving security of payment, particularly of smaller subcontractors. Moreover, claimants are most successful at adjudication if the respondent does not provide the claimant with a payment schedule. This finding seems to reinforce the previous observation of respondents' poor knowledge of the Act.

The results also show that while claimants attempt to inflate the value of their payment claims particularly of large claims, respondents consistently engage in undervaluing such claims. It seems that the NSW Act is yet to succeed in discouraging the parties from engaging in the practice of either unduly inflating or undervaluing progress payments.

Adjudication fees appear to be modest enough to conclude that adjudication provides claimants with a relatively inexpensive means of determining disputes as to payment by an independent third party. Of greater concern are the indirect costs of adjudication, particularly those related to the cost of lawyers or claims consultants.

Further research is needed in order to verify or otherwise the real cost/benefits of adjudication under the NSW Act.

Overall, the findings of the research show that the changes made to the Act in 2003 have significantly increased the number of adjudication applications made particularly by subcontractors, which is indicative of the growing popularity of the adjudication process in NSW. The findings also suggest that the main aim of the Act to improve security of payment in the NSW construction industry has, to a large extent, been achieved. These findings may assist legislators in other Australian States to develop new legislative schemes or amend existing ones in line with the successful NSW Act.

REFERENCES

Brand, M C and Uher, T E (2004) The performance of the Security of Payment Act in the Australian construction industry. *In*: H Elmahdy (Ed.) *CIB World Building Congress*, 2–7 May 2004, Toronto, Canada. CD-ROM. International Council for Research and Innovation in Building and Construction, Paper 250.

Davenport, P (2003) Security of payment in NSW – significant changes. *Australian Construction Law Newsletter*, **88**(January/February), 25–8.

Davenport, P (2004) *Adjudication in the building industry*. 2ed. Sydney: The Federation Press.

Commonwealth of Australia (2002) Royal Commission into the Building and Construction Industry: Security of payment in the building and construction industry. Discussion Paper 12. Canberra: Commonwealth of Australia.

Iemma, M, Rt Hon (1999) Second Reading Speech (Hansard) – Building and Construction Industry Security of Payment Bill (NSW), NSW Legislative Assembly, 8 September.

NSW Department of Commerce (2004) *Building and Construction Industry Security of Payment Act 1999 – review report May 2004: payment problems?* Sydney: NSW Government.

NSW Department of Commerce (2005) *Building and Construction Industry Security of Payment Act 1999 – progress report*. Reporting Month – 31 December 2005. Sydney: NSW Government.

NSW Department of Commerce (2006) *Building and Construction Industry Security of Payment Act 1999 – progress report*. Reporting Month – 30 June 2006. Sydney: NSW Government.

NSW Government (1996) Green Paper: security of payment for subcontractors, consultants and suppliers in the New South Wales construction industry. *Australian Construction Law Newsletter*, **51**(March/April), 41–51.

Uher, T E and Brand, M C (2005) Analysis of adjudication determinations made under security of payment legislation in New South Wales. *International Journal of Project Management*, **23**(6), 474–82.

MISCONCEPTION ABOUT THE USE OF THE STANDARD METHOD OF MEASUREMENT IN DEVELOPING COUNTRIES: A GHANAIAN PERSPECTIVE

Gabriel Nani[1], Anthony Mills[2] and Theophilus Adjei-Kumi[1]

[1]*Building Technology Department, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[2]*School of Property Construction and Project Management, RMIT University, Melbourne, Victoria 3000, Australia*

Bills of Quantities are the classical form of financial control used for pricing construction projects throughout much of the developed world. The British-based Standard Method of Measurement (SMM) is widely used throughout Developing countries for generating bill of quantities. However the nature of the construction industry is very different and the SMM is routinely adapted to suit local conditions. This research investigates the typical local conditions that cause departures in the adoption and use of SMM in developing countries. The paper examines some commonly held, but often false assumptions, about how the SMM is applied in developing countries: Ghana. A questionnaire survey approach was used in obtaining information from industry practitioners, while comparisons are made to some developed countries (UK). This has implication for the development of information technology (building information modelling) and international firms that undertake work throughout the world. The paper concludes with the impacts of the departures from the SMM to the international construction community.

Keywords: standardization, measurement, quantity surveying, estimating, information technology, developing countries.

INTRODUCTION

The standard for measurement of construction works is a formal document that sets out the conventions for defining the nature of construction works, how the work is measured or taken-off and quantified (Earley and Gould 2004). This document sets the basis for preparation of bill of quantities which is often used to model cost. The general relevance of SMM is demonstrated by the usefulness of bill of quantities. Ferry *et al*. (1999) noted that Bill of Quantities (BQ) is a total cost model which could be used for various purposes both within the client organization and the contractor's organization. Singh and Banjoko (1990) corroborated this, while researching to produce a 'rational bill' for the civil engineering industry. They discovered that, at the heart of civil engineering measurement projects is financial control, whose satisfactory performance is influenced by how the structure of the construction cost is modelled by the BQ. Other researches confirmed the usefulness of BQ (hence SMM) for cost modelling among other uses such as quality or specification control, and

[1] gabrielnani@yahoo.com

scheduling of activities (Kodikara *et al.* 1993; Law 1994; Nani and Adjei-Kumi 2007).

Standard Method of Measurement (SMM) for works of construction is common with commonwealth nations. In some commonwealth countries, a local SMM is used for measuring works of construction while other countries adopt standard methods from other countries. The most widely adopted standard method of measurement is the British SMMs (Mills *et al.* 2006). About 20% of the total number of countries surveyed in a global survey of SMMs in current use (RICS Construction Faculty 2003), adopted a British standard method of measurement. The rest of the countries (i.e. 80 %) use a form of measurement standard produced locally. Ghana is one of the countries that have adopted the British measurement standards for measuring construction works.

Contrary to the spirit of the British standard methods of measurement, there are some departures from the manner in which they are used in Britain and how they are used in Ghana. The paper investigates the differences in the adoption and use of SMM in UK and in developing countries (using Ghana as a case study). These differences are of relevance to the international community, as international firms doing business in Ghana and other developing countries need to note the local norms and practices of measuring work.

A questionnaire with open-ended and close-ended questions were used to illicit information from quantity surveyors practising in recognized professional quantity surveying firms. The questions require the selection of response from alternatives followed by the respondent's comments. This approach provided the respondent the flexibility to dilate upon their responses and provide further useful information. The respondents were asked to state the differences in the construction industry between Britain (where the SMMs used in Ghana were developed) and Ghana, which have bearing on adoption of SMM. They were further required to point out departures with the application of British SMM in Ghana. They also indicated whether they carry out work for contractors or consultants. This is expected to ensure results represent views from both the consultants' and the contractors' perspectives

The population of quantity surveyors was selected based on their experience with SMMs (they are in constant study and application of SMM). There are fifty seven recognized professional quantity surveying firms in Ghana (Ghana Institution of Surveyors 2006a). Questionnaires were hand-delivered to three randomly selected Quantity Surveyors in each of the 57 firms. Sixty respondents spread over 27 firms returned their questionnaire. This indicates about 35% response rate from Quantity Surveyors spread over 47% of the total number of firms consulted.

In addition 68% of the respondents indicated that they have ever carried out measurement as contractor's quantity surveyor. This indicates that the contractors' perspective is represented in the survey. Other results and comments obtained from the respondents are discussed together with literature review in the ensuing paragraphs.

NATURE AND DIFFERENCES IN THE CONSTRUCTION INDUSTRY IN THE DEVELOPING AND DEVELOPED COUNTRIES

The respondents stated emphasis on project control, standardization construction products and materials, technology and culture as aspects of the construction industry where differences (which affect SMM) exist between developed and developing countries.

52% of the respondents indicated that developing countries emphasize cost control more quality and time control in a project environment. This corroborates Kazi and Charoenngam (1999) observation that the need to control project cost, is paramount to developing countries, since infrastructure development continues to be a priority. They also acknowledged that time and quality control is far less emphasized as compared to cost (Ofori 2000; Shakantu *et al.* 2002). Ogunsemi and Jagboro (2006) also observed that time and cost overruns are rampant in the Nigerian construction industry. They cited Odusami and Olusanya (2000) in a research which showed that projects executed in Lagos Nigeria do overrun their time in excess of 51% of the planed duration. As a result, SMM in a developing country seeks to first address issues of cost as compared to developed countries who pay equal attention to quality and time specifications.

71% of the respondents identified standardization of construction materials and products as poor in Ghana as compared to the UK and other developed countries. As a result, there is influx of materials and products with assorted standards from both internal and external sources. Natural market sizes of some locally produced materials are at variance with what prevails in other developed countries. Most respondents cited the length of timber as example. The maximum continuous length is 4.80 metres, while the British SMM acknowledges a length of 6.00 metres.

About 87% of respondents cited technology levels especially with respect to industrialization of construction process are low in Ghana as compared to other developed countries. They mentioned the presence of craft based large labour force (carrying out work otherwise carried by plants) and few plants on construction sites as evidence. In situ construction is also cited as common compared to pre-cast construction. These influence the practice of the industry, hence any measurement approach adopted for construction works. SMMs in these countries therefore focus on labour intensive and insitu construction rather than the industrialized form of construction.

76% of the respondents stated culture as a major factor that influences the nature and distinguishes construction industries. Cultural differences can be viewed in terms of focus in business. This affects the type of emphasis that is placed on measured construction work. They confirmed that, construction business in Ghana as in most developing countries in Africa is relationship focused unlike most industrialized countries (including UK), where it is deal focused (Langford 2000). This means that business is usually between friends, relatives, and people well known to one another (termed locally as ‘whom you know’). Further comments by respondents explained that, Trust based on relationship between parties has reduced the emphasis placed on highly detailed and accurate measurement of construction work. This has reduced the burden on the quantity surveyor. On the other hand as depicted in the seventh edition of the British standard method of measurement of building works (SMM7), most developed countries emphasize detailed and highly accurate measurement procedures – there may be suspicion of one party taking advantage of the other (Langford 2000). This cultural difference reflects in application of construction contract conditions, hence the rules of SMM. Elimination of cost insignificant items and Simplification of SMM is therefore possible in these developing countries.

COMMONLY HELD BUT OFTEN FALSE ASSUMPTIONS ABOUT THE APPLICATION OF SMM

The function of SMM is to provide the basis for preparing Bill of Quantities which is used to model and control construction cost

Though the SMM is used in preparing Bill of Quantities (BQ) which is used mainly in cost control (Kodikara *et al.* 1993), it also aids specification writing and scheduling of construction activities. 75% of respondents confirmed these other uses for SMM and stated its provision of a ready classification for specification writing and preparation of works programme. Further comments stated that in situations where complete information can not be obtained from available drawings, BQ are consulted for information on specifications and extent of work. The limit of the information obtainable is determined by the SMM used (in this case the SMM is providing specification information). The most commonly omitted specifications in Ghana include painting type and colour scheme, door and window details, fittings and fixtures details, among others. In other instances specifications are incoherent and BQ are consulted for clarification. In the preparation of schedule activities, project managers consult the BQ (though in conjunction with other documents) mainly to determine the extent or volume of work required to be carried out. Their understanding of what the quantities in the BQ mean is based on the SMM used.

The most commonly used standard method of measurement in Ghana is SMM7

69% of respondents in this survey use SMM5 as against 20% for SMM7 and 11% for SMM6 and other methods of measurement. This finding corroborates an earlier finding that SMM5 is used on 65% of the occasions measurement is carried out in Ghana (Nani and Adjei-Kumi 2007). This is contrary to the international surveys (RICS Construction Faculty 2003; Mills *et al.* 2006) that indicate SMM7 is the standard method of measurement for building works used in Ghana. It is in December 2006 that the Ghana Institution of Surveyors (GhIS) declared the compulsory use of SMM7 in Ghana, effective July 1, 2007 (Ghana Institution of Surveyors 2006b). According to respondents, persistent use of SMM5 is due to the fact that most recognized quantity surveying firms in Ghana today were established by principal partners who had their education in the 1970s and 1980s when SMM5 was used in training quantity surveyors. The Ghanaian construction industry also shows characteristics of a craft industry that is better modelled (in terms of quantities and cost) by SMM5 than SMM7. Further, low industrialization of construction, low standardization of construction materials and incomplete documentation at the point of preparing BQ deprive the industry from fully benefiting from the provisions of SMM7.

SMMs are adopted indiscriminately

Most SMMs adopted are not without amendment or abridgement. All respondents who use SMM5 in preparation of bill of quantities and 75% of those who use SMM7 indicated that they modify the measurement rules. This assertion was confirmed by a critical examination of BQs prepared within the respondents firms. The amendments include omission of quantities for cost insignificant items (such as making good concrete work associated with holes, builders work, trimming, labours etc.), aggregation of certain like work items (mullions, transoms, jambs, heads and sills for timber windows and door frames; external and internal finishes when they of the same material etc.), adoption of units contrary to SMM5 (e.g. finishing works in narrow strips, which SMM5 rules requested should be measured linear are measured superficial). These amendments were made possible by the factors discussed as contributing to the nature and differences in the construction industries of developing and developed countries. Low levels of wages for construction workers in Ghana make most labour items in SMM5 insignificant with respect to cost in the Ghanaian context as compared to UK and Australia. For instance an unskilled labourer in Ghana receives an average of Fifty Thousand cedis (¢50,000) per day (equivalent to £2.7), which is less than the hourly rate in the UK.

The adoption of SMM is an agreement between the Contractors and the Quantity Surveyors' professional body

All respondents agreed that SMM5 and other versions of SMM used in Ghana were not selected based on the collective agreement between the Quantity Surveyors professional body and the Contractors association in Ghana. This is contrary to what prevails in the UK, and stated in the preface to SMMs developed in the UK. This appears to be the case with most SMM in various other developing countries as observed in few SMM developed for those countries (Wood and Kenley 1997; N.I.Q.S. 2003; Mills *et al*. 2006). Though, the British SMM was approved by the Ghana government conditions of contract, and most contract conditions in Ghana, the respondents are of the opinion that the contract conditions are imposing the SMM on the contractors. The SMM and its necessary amendments are usually introduced in tender documents by Quantity Surveyors and the contractors are expected to either accept or leave it. The adoption of SMM5 is therefore not an agreement but a unilateral decision by the QS professional body. Though this appears to be a recipe for disputes (with respect to measurement approach), it hardly occurs. The respondents explained this by indicating that most estimators, quantity surveyors and project managers in the Ghanaian construction industry also belong to the GhIS (the Quantity Surveyor's professional body that adopted the SMM). Further, trust developed through working with relations could also be a reason (Langford 2000).

Quantity Surveyors constantly consult the SMM

70% of respondents confirmed the general conception that Quantity Surveyors are in constant touch with SMM. This was however found not to be true as 90% of the respondents use BQ from previous projects to prepare one for new projects rather than prepare them from scratch using an SMM. Consequently, 49% of respondents could not trace their office copies of SMM immediately (though younger Quantity Surveyors were able to retrieve their student copies of SMM7). It was explained that experience has enabled the Quantity Surveyors to carryout their measurement duties in accordance with the SMM and the abridged rules without constantly consulting it. The younger Quantity Surveyors were able to retrieve their copies because they are less experienced, hence consult the SMM more frequently.

Both practice and academia use the same SMM

This assumption was also found to be false during the survey as it was discovered hat that while SMM5 is mostly and still used in practice, the academia began using SMM7 for more than a decade ago. Though students study the principles of measurement, which is mostly the same irrespective of the SMM used; Quantity surveyors who use SMM5 and other methods of measurement indicated that, they re-train new graduates. This enables them to be proficient in the use of SMM5 before they are fully absorbed into the industry. The differences between SMM5 and SMM7 are with the structure of the SMM (i.e. from prose form to tabular form), the use of new classification system (i.e. CAWS or UNICLASS instead of the traditional work sections), and the industrialized building construction approach rather than the traditional labour intensive approach.

IMPLICATIONS FOR INFORMATION TECHNOLOGY

The above discussions suggest a generally flexible and user (regional user) defined method of measurement for the construction industry. The ability of various regional factors such as culture, existing standards, and technology levels to influence the method of measurement of construction works implies software developers must adopt similar flexible approach in order to satisfy clients universally. Building information models (BIM), a recent development in information technology is required to provide 'one-stop' information on all aspects of a project including cost models such as BQ. BIM is defined as a set of interacting policies, processes and technologies producing a methodology to manage the essential building design and project data in digital format through out the building's life-cycle of the project (Pentilä 2006). It may require in-built SMM in order to carry out its cost modelling function such as measurement and compilation of quantities information for a project. Provision must therefore be made for regional customization of the in-built SMM to cater for the factors discussed which may affect the method of measurement. The assumptions about the application of SMM are consequently worthy of note by software developers who work on building information models.

CONCLUSION

The discovery of this survey is relevant to international construction firms that intend to carry out business in Ghana and other developing countries. It is necessary for these firms to understand the cultural technological and other differences that exist between these countries and the developed countries. The differences and the misleading assumptions identified are signals to the international construction community to be cautious, whenever they encounter an SMM or similar document, which is adopted in a country other than its purported country. A complete knowledge of how the SMM is adopted prevents misunderstanding, multiple measurement and payment for work. The finding of this paper gives an insight into some issues, international firms should consider while recovering cost and value for projects in developing countries. Further research is recommended to improve the role of SMM in BIM cost modelling.

REFERENCES

Earley, M and Gould, H F (2004) Current topic: standard method of measurement. Available at: www.rics.org

Ferry, D J, Brandon, P S and Ferry, J D (1999) *Cost planning of building.* Oxford: Blackwell Science.

Ghana Institution of Surveyors (2006a) Quantity surveying firms. *Newsletter*, **4,** 12.

Ghana Institution of Surveyors (2006b) Standard Method of Measurement (SMM7). *Newsletter,* **4,** 12.

Kazi, A S and Charoenngam, C (1999) A cost analysis information system for developing and underdeveloped countries. *Cost Engineering,* **41,** 29 -36.

Kodikara, G W, Thorpe, A and McCaffer, R (1993) The use of bill of quantities in the building contractor organizations. *Construction Management and Economics,* **11,** 261 - 69.

Langford, D (2000) The influence of culture on internationalisation of construction. *2nd International conference on Construction.* University of Strathclyde.

Law, C (1994) Building contractor estimating: British style. *Cost Engineering,* **36,** 23-8.

Mills, A, Lawther, P and Jones, D (2006) Standard Methods of Measurement – A comparative study of national and regional publications. Australian Institute of Quantity Suveyors and Royal Institution Chartered Surveyors.

N.I.Q.S. (2003) *Building and engineering standard method of measurement.* 2ed. Lagos: Nigerian Institute of Quantity Surveyors.

Nani, G and Adjei-Kumi, T (2007) The challenges of quantifying construction works for project control in Ghana. CIB World Building Congress. Convention Centre, Cape Town.

Odusami, K T and Olusanya, O O (2000) Client's contribution to delays on building projects. *The Quantity Surveyor*, **30,** 30-3.

Ofori, G (2000) Challenges of construction industries in developing countries: lessons from various countries. *The 2nd international conference of the CIB TG29: construction in developing countries.* 11 – 17 November, Gaborone, Botwana.

Ogunsemi, D R and Jagboro, G O (2006) Time-cost model for building projects in Nigeria. *Construction Management and Economics,* **24,** 253-58.

Pentilä, H (2006) Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *ITCon*, **11**, 395 - 407.

RICS Construction Faculty (2003) International survey 2003: Standard Methods of Measurement in current use. Royal Institution of Chartered Surveyors.

Shakantu, W, Zulu, S and Matipa, W M (2002) Global drivers of change: their implications for the Zambian construction industry. *Proceedings of the 1st International Conference of CIB W107: Creating a Sustainable Construction Industry in Developing Countries.* 11 – 13 November, South Africa.

Singh, G and Banjoko, O O (1990) The development of a rational Bill of Quantities. *Construction Management and Economics,* **8,** 31.

Wood, B M and Kenley, R (1997) The standard method of measurement and the abridged bills of quantities: a review of the Australian context T3 - N1 - ANALYTICAL N1. *Australian Institute of Building papers,* **8,** 77.

THE DIFFERENCE BETWEEN THE BQ AMOUNTS AND THE REMEASURED AMOUNTS ON REMEASUREMENT CONTRACTS IN RENOVATION WORKS OF HOUSING COMPLEXES IN JAPAN

Tetsukazu Akiyama[1]

Department of Architecture, Toyo University, 2100 Kujirai Nakanodai, Kawagoe, Saitama 350-8585, Japan

In renovation work contracts for housing complexes in Japan, a lump-sum fixed price contract is generally adopted, which is not the risk the construction cost change after it contracts. In renovation works, the amount of increase and decrease is generated. It is improper to adopt the lump-sum fixed-price contract; the remeasurement contract is preferable. The aspect of the main analysis is the actual condition of the cost change according to the increase and decrease of the BQ and additional/deleted works, and the attribution analysis. This study analysed progressive consultants who employ remeasurement contracts for renovations of housing complexes to find out the difference between the provisional quantities written in contracts BQ and the remeasured actual quantities written in final documents after the completion of renovation works through 27 renovation projects. It has been understood that the difference of BQ amounts for each project is large, and that the amount of the increase and decrease by additional/deleted works is larger than amount of increase and decrease of BQ. It is necessary to examine the validity of the contingency based on the experience.

Keywords: remeasurement contract, renovation work, housing complex, bills of quantities.

BACKGROUND OF THIS STUDY

When housing complexes are renovated, renovation contracts are made by the owners associations (ordering party) according to the resolution of their general meetings. Therefore, they tend to prefer lump-sum fixed-price contracts, which carry no risk of price changes after contracts have been agreed. However, the details of renovation work are rather uncertain because repair-work specifications and the assessment of work quantities depend on the accuracy of preliminary inspections. Owners associations are usually unwilling to spend much money on preliminary inspections, and there are many renovation consultants who plan repair budgets based on rough estimation per housing unit (or per floor area). Despite uncertain factors in details of renovation work, lump-sum fixed-price contracts are employed in most renovation projects.

If there are uncertain factors in renovation plans, the risks of lump-sum fixed-price contracts are to be borne by contractors. If extra places were found to be in need of repair in the course of renovation work, they would have no choice but to modify

[1] akiyama@eng.toyo.ac.jp

renovation procedures since prices cannot be increased or decreased. This situation can also cause quality problems.

Some recent standard specifications prepared by expert consultants for renovation work on housing complexes have included repair-work items that are to go through quantity remeasurements at later stages. For example, looking at “Practical Specifications for Renovation Work on Housing Complexes and Explanations”, produced under the supervision of the Japan Institute of Architects (JIA 1998), certain items that should undergo quantity remeasurements are listed in particular specifications. Thus, specifications clearly indicate that it is impossible or very difficult to determine the exact quantities of certain items at the time of agreeing a contract. This is because when drawing up estimation breakdown sheets, most consultants (designers) grasp damage conditions only through visual inspections without scaffolding or through hammering tests on limited areas. The quantities of rusted reinforced steel, cracks, and loose mortar and tiles are assessed based on the contractor’s experience and judgment.

OBJECTIVES AND METHODS OF THE STUDY

Objectives and methods of the study

Although lump-sum fixed-price contracts are commonly used in renovation projects, some progressive consultants are actively introducing remeasurement contracts and requesting the adjustment according to actual figures or contingency in order to prepare for uncertainties in renovation work.

This study analysed four consultants (architect offices) that employ remeasurement contracts for renovations of housing complexes to find out the following: (1) the characteristics of renovation contracts containing remeasurement items; (2) budget planning and contingency of renovation works; and (3) the difference between the provisional quantities written in contracts BQ and the remeasured actual quantities written in final documents after the completion of renovation works.

For this study, contractual renovation priced BQ and remeasured actual renovation priced BQ were collected from 27 renovation projects that were designed and supervised by the four consultants and completed in 2000–2004.

The aspect of the main analysis is the actual condition of the cost change according to the increase and decrease of the bills of quantities and additional works and the deleted works, and the attribution analysis.

Profiles of surveyed consultants

The following four consultants were surveyed.

Consultant A

Consultant A engages in renovation on housing complexes mainly in the Kansai region. Its representative also heads a non-profit organization corporation, the “Housing Complex Improvements Center”. Basically, this consultant does not spend much time and effort on damage inspections. It considers that spending money on preliminary inspection is ineffective because no matter how rigid inspections are, quantity revisions are inevitable for remeasurement items. When asked for estimates, consultant A provides provisional (projected) quantities based on previous experience and results. Notably, its written contracts come with itemized statements that record any questions and answers. The minutes of owners-association meetings are generally attached to renovation contracts; some minutes specify the amount of contingency.

Consultant B
This consultant specializes in renovation work and operates mostly in the Tokyo metropolitan area. It is a member of Renewal Technology Development Committee, of which the chairperson is the representative of Consultant B. When undertaking renovation of housing complexes, it conducts extensive damage inspections before drawing up estimations. Its estimation sheets describe provisional quantities for remeasurement items and reference quantities. If reference quantities are to be altered, contractors must explain the reasons for this; thus, reference quantities should be quite close to committed quantities.

Consultant C
This consultant operates in the Tokyo metropolitan area and also conducts design and consulting for new houses. Its representative is a principle member of JIA's condominium committee and an editorial supervisor of JIA's "Practical Specifications…" document (1998), which was issued by the committee. This consultant also inspects buildings briefly for the same reason given by consultant A. It firstly sets per-housing-unit costs based on its experience, and then calculates total renovation costs by taking into account the specifications of renovation works. The composition of estimation sheets is similar to that of consultant A. Consultant C is planning to develop a database of estimations and others.

Consultant D
This consultant operates mainly in the Tokyo metropolitan area, focusing on design and consultation for renovation on housing complexes. Its representative is also a principle member of JIA's condominium committee and an editorial supervisor the afore-mentioned report, along with the representative of consultant C. This consultant does not spend much time and effort on damage inspections. It is a characteristic of this consultant to conduct a second round of renovations for existing condominium buildings. This consultant is active in the improvements of building structures, including the introduction of the external thermal insulation method.

All these four consultants adopt remeasurement contracts, but they use different terms in remeasurements (e.g.: provisional quantities, projected quantities, specified quantities, predicted quantities, contract quantities, etc.) They also differ in the way in which they explain the necessity of remeasurement-related contingency to owners associations and in the methods of instructing contractors about such funds. Thus, each consultant is independently conducting business based on his own experience.

THE ESTABLISHMENT OF REMEASUREMENT ITEMS

The "Practical Specifications…" report, issued by the condominium committee of JIA (1998), describes: "1) Remeasurement items, listed in particular specifications, should be adjusted through the calculation of difference between contractual quantities and actual quantities based upon unit price; and 2) The tentative quantities for remeasurement items as a basis for contracts are referred to in particular specifications." In other words, the existence of remeasurement items is mentioned in "general common items (general conditions)" of specifications, and specific items are stated in particular specifications. Consultant A provides "projected quantities" for remeasurement items in itemized lists, which are attached to renovation contracts. In the case of consultant B, the presence of remeasurement items is mentioned in its “general common items”, which read: “Estimated quantities : After on-site meetings, if contractors should have questions regarding presented estimation quantities (excluding remeasurement items in the reference column of estimation itemized lists).” Remeasurement items are separately described in its itemized estimation lists. The specifications of consultant C and D follow JIA’s style.

Each consultant sets up remeasurement items according to their experience (Table 1). This study compared each consultant’s remeasurement items presented in written estimates with remeasurement items in JIA’s material (1998) as the basis of comparison. Looking at the remeasurement items of each consultant in comparison to those of JIA, it can bee seen that almost the same work items are listed as major categories (repair work on tiles, mortar, sealing, exterior-wall painting, waterproofing and steel parts). However, on the subcategory and item levels, each consultant uses different terms to describe the details of remeasurement items.

All the consultants show provisional quantities for remeasurement items. For some items, only unit price is provided without quantities because those items were not expected when signing contracts but they may possibly arise in the course of renovation work.

Table 1: The composition and details of remeasurement items in remeasurement reports

JIA	Consultant A	Consultant B	Consultant C	Consultant D
1. Improvement of concrete frame	1. Repair of damaged furring	1. Improvement of building frame	1. Repair of cracks	1. Improvement of exterior wall and frame; waterproofing
2. Repair of cracks on concrete frame and mortars	2. Repair of reinforcing bar	2. Improvement of mortar	2. Repair of exposed reinforcing bar	
3. Repair of loose mortar and peeled or damaged interface	3. Repair of exterior tiles	3. Improvement of waterproofing on rooftops	3. Repair of loose materials	
4. Improvement of exterior tiled area	4. Repair of cracks	4. Improvement of metallic parts	4. Repair of leaking mortar parts	2. Spraying and painting of exterior wall
5. Improvement of sealing	5. Caulking and sealing work	5. Improvement of doors and windows	5. Improvement of furring and exterior wall	
6. Improvement of mortar waterproofing	6. Waterproofing work	6. Miscellaneous works	6. Caulking and Sealing work	3. Improvement of waterproofing
7. Repair of steel/ hardware parts	7. Painting work	7. Caulking and Sealing work	7. Painting work on steel parts	4. Improvement of metallic area; painting of steel part; polishing and cleaning
		8. Painting work		

BUDGET PLANNING AND CONTINGENCY

The consultants sum up the contingency before undertaking the contract because of the remeasurement contract. The amount of contingency requested by each consultant is as follows. The ratios of these contingencies are not set based on the experience of each consultant, and are not based on accurate grounds. Consultant A asks for 5% of contracted prices (renovation costs including overhead expenses incurred) or 10% of those if budgets are sufficient; consultant B asks for 10% as contingency; consultant C asks for 5% of contracted prices; and consultant D asks for 5–10%. In the case of consultant A, which attaches the minutes of owners-association meetings to renovation contracts, the amount of contingency is sometimes specified in the minutes of these meetings. This consultant aims to gain the understanding of owners associations (ordering party) regarding the necessity of contingency, and also to establish the consensus of association members through their discussions. In this method, the contingency budgets are disclosed to contractors, which requires consultants to be more responsible and skilful in cost management in the supervision process.

The explanation of the necessity of the contingency at budget plan stage and the presentation of an appropriate ratio of the contingency and the severe cost management capability at construction stage is expected to be the consultant's role.

HOW TO DECIDE PROVISIONAL QUANTITIES IN RENOVATION PLANS

The surveyed consultants showed the difference in attitude about the costs of preliminary inspections conducted before drawing out renovation plans.

There are two types of inspection. One is a simple inspection based on visual inspection within the extracted parts that can be inspected easily. The other is a detailed inspection with a partial destruction test and as much as possible to be inspected.

Consultants A, C and D conduct visual inspections and estimate provisional quantities per housing unit or floor area based on their experience, rather than carrying out rigid inspections and spending more money. Their opinion is that estimated quantities are subject to change no matter how rigid preliminary inspections are, and that it is reasonable to allocate more budget to repair works rather than spending money on preliminary inspections.

On the other hand, consultant B conducts rigid inspections, so inspection costs are relatively high. This consultant is pursuing the accuracy of renovation plans through extensive inspections. For example, the consultant uses scaffoldings for some parts of the inspection. Based on such detailed inspections, consultant B calculates estimation quantities for an entire project at the first stage. Then, it applies safety factors based on its experience and determines provisional quantities for each damage item (such as the exposure of reinforcing steel, cracked tiles, cracks in painted areas, loose tiles, leaks and partial breakages) and also for each repair work. The consultant prepares for contingencies by making estimations with safety factors for some remeasurement items that may cause major cost alternations. The ratio of the contingency of consultant B presents 5% because of their close inspection.

As mentioned above, in renovation work on housing complexes, the methods of deciding provisional quantities depend on consultants. There are two major approaches: one is to provide rough estimation per housing unit (or floor area) based on their experience, and another is to work out quantities through rigid inspection.

THE ANALYSIS OF CONTRACTUAL/PROVISIONAL QUANTITIES AND REMEASURED QUANTITIES

For this study, contractual renovation priced BQ and remeasured actual renovation priced BQ were collected from 27 renovation projects that were designed and supervised by the four consultants and completed in 2000–2004. Their remeasurement BQ reports contain specified work items for remeasurement, specifications, work units, unit rate, provisional quantities, provisional rate, remeasured quantities, remeasured rate and differences in amounts.

At first, I attempted to study the rates of change in quantities for each work item. However, since work items were dispersed and some of the specifications had been altered, I analysed differences in costs through multiplying quantities by unit cost. In this analysis, the specification change becomes a cost reimbursement treatment by not the remeasurement but additional construction. As for the specification change, a detailed analysis of the addition is necessary.

Table 2: Details of the difference between provisional costs and remeasured costs (shown in thousands of yen)

	Contractual net renovation cost	Change in cost	Cost rise due to quantity increase	Cost fall due to quantity decrease	Cost rise due to additional work	Cost fall due to deleted work
A-1	159,924	9.02%	13.58%	-1.79%	11.51%	-14.29%
A-2	199,830	5.01%	10.03%	-5.38%	2.59%	-2.23%
Average of A		7.02%	11.81%	-3.59%	7.05%	-8.26%
B-1	78,367	-7.68%	4.74%	-5.96%	2%	-8.46%
B-2	57,153	7.39%	2.60%	-6.27%	23.14%	-12.09%
B-3	36,247	0.36%	3.11%	-12.04%	11.66%	-2.37%
Average of B		0.02%	3.48%	-8.09%	12.27%	-7.64%
C-1	29,733	1.11%	2.43%	-1.32%	1.56%	-1.56%
C-2	44,705	0.92%	0.73%	-1.86%	2.72%	-0.67%
C-3	47,878	1.75%	1.19%	-0.22%	2.02%	-1.24%
C-4	43,883	3.85%	2.44%	-0.64%	3.30%	-1.24%
C-5	42,016	-1.26%	0.56%	-3.13%	1.89%	-0.58%
C-6	66,257	0.27%	0.24%	-2.16%	2.40%	-0.22%
C-7	41,195	4.92%	1.38%	-2.95%	6.97%	-0.48%
C-8	85,205	0.19%	0.16%	-2.41%	2.25%	-0.18%
C-9	17,842	8.10%	8.08%	-5.55%	10.55%	-4.98%
C-10	22,078	-0.36%	12.68%	-8.14%	4.56%	-9.46%
C-11	15,205	-2.70%	15.15%	-10.67%	4.72%	-11.91%
C-12	18,241	15.42%	11.14%	-6.15%	19.50%	-9.07%
C-13	25,943	8.13%	12.60%	-5.32%	10.33%	-9.48%
C-14	26,538	9.24%	9.41%	-6.01%	11.06%	-5.23%
Average of C		3.54%	5.59%	-4.04%	5.99%	-4.02%
D-1	46,197	0.88%	3.97%	-2.82%	9.78%	-10.06%
D-2	40,157	4.29%	3.05%	-2.87%	13.48%	-9.37%
D-3	12,768	4.04%	4.62%	-3.27%	10.76%	-8.07%
D-4	33,449	2.67%	4.04%	-2.98%	17.31%	-15.70%
D-5	17,128	1.41%	4.67%	-2.64%	13.13%	-13.75%
D-6	210,981	7.79%	2.81%	-2.49%	20.85%	-13.38%
Average of D1 6		3.51%	3.86%	-2.85%	14.22%	-11.72%
D-7	136,997	2.98%	0.99%	-1.47%	6.15%	-2.69%
D-8	57,603	-6.68%	4.40%	-11.06%	4.10%	-4.12%
Average of D7,D8		-1.85%	2.70%	-6.27%	5.13%	-3.41%
Total average	1,613,520	3.00%	5.21%	-4.35%	8.53%	-6.40%

Column 1; contractual net renovation cost (shown in thousands of yen)
Column 2; the rates of change in cost = the sum of cost change after remeasurement/contractual net renovation cost

Column 3; the rates of cost rise due to quantity increase = the sum of cost rise due to quantity increase/ contractual net renovation cost
Column 4; the rates of cost fall due to quantity decrease = the sum of cost fall due to quantity decrease/ contractual net renovation cost
Column 5; the rates of cost rise due to additional work = the sum of cost rise due to additional work/ contractual net renovation cost
Column 6; the rates of cost fall due to deleted work = the sum of cost fall due to deleted work/ contractual net renovation cost

In addition, ordering parties and consultants decide on contingencies by setting the amount of the total project cost as 100%. However, ordering parties and contractors usually conduct cost negotiations and miscellaneous expenses (such as field overheads and general administration costs) are often deducted from total project costs. In some cases, project costs are virtually reduced through the one-sided discount from contractors. Therefore, the meaning of work quantities derived by adding up itemized quantities and the meaning of unit cost come to be obscure. In this study, the rates of change between provisional costs and remeasured costs have been calculated on the basis of net renovation costs (direct renovation costs + temporary work costs).

The analysis below focused on the difference between provisional and remeasured costs provided by the four consultants. Table 2 shows the following cost-variation rates to contractual net renovation costs for each project: rates of cost change after remeasurement; rates of cost rise due to quantity increase; rates of cost fall due to quantity decrease; rates of cost rise due to additional work; and rates of cost fall due to deleted work.

Overall trend
This data focused on 27 renovation projects conducted by the four consultants (the aggregate renovation costs of 1.6 billion yen; 62 buildings, 2,332 housing units). According to this, the remeasured renovation costs increased by an average of 3.0% from initial and contractual net renovation costs. In detail, the average rate of cost rise due to quantity increase was 5.2%, and the average rate of cost fall due to quantity decrease was 4.4%. As a result, the rate of cost change due to the change of quantities was plus 0.8%, which was a small difference.

On the other hand, the rate of cost rise due to additional work was 8.5%, and the rate of cost fall due to deleted work was 6.5%, showing larger differences than those resulting from quantity changes. The increased costs due to additional work were largely offset by the decreased costs due to deleted work, but resulting in a cost increase of 2.0%. It appears that preliminary renovation plans should be more specific about additional work.

Remeasured results of consultant A (2 projects: 5 buildings with 270 units; and 6 buildings with 200 units)
The remeasured renovation costs increased by 7.0% from the provisional costs. This is a fairly high rate and the increased amount needs to be covered by contingency. Looking at its breakdown, the rate of cost rise due to quantity increase was considerably high at 11.8%. Meanwhile, the rate of cost fall due to quantity decrease was 3.6%. The rate of cost rise due to additional work was also high at 7.1%, which was offset by the rate of cost fall due to deleted work. Even if eventual increase in cost fell within the amount of contingency, there were a lot of cost fluctuations.

Remeasured results of consultant B (3 projects: 1 building with 88 units; 1 building with 105 units; and 1 building with unknown number)
This consultant conducts rigid preliminary inspections compared to consultants A, C and D. Its average rate of cost change from provisional costs was 0%. The rate of cost rise due to quantity increase was low at 3.5%, while showing the highest rate of cost fall due to quantity decrease of 8.1%. These results reflect the effects of its rigid preliminary inspections and quantity calculations with safety factors. However, the rate of cost rise due to additional work and the rate of cost fall due to deleted work were both high at 12.3% and 7.6%, respectively, and these rates of change greatly depended on projects.

Remeasured results of consultant C (14 projects: 30 buildings with 745 units (divided into 8 sections); and 6 buildings with 456 units (treated as 6 projects))
The data on consultant C are based on renovation projects on two large housing complexes. In Table 2, projects on one of the housing complexes are described as C-1 to 8 and projects on the other as C-9 to 14. They are treated as separate projects because of the difference in design, structures and accountings of contingency. The rate of change from the provisional costs was relatively stable at > 3.5%. The rate of cost rise due to quantity increase was 5.6%, and the rate of cost fall due to quantity decrease was 4.0%. The rate of cost rise due to additional work was 6.0%, and the rate of cost fall due to deleted work was 4.0%. The rates of cost change due to additional or deleted work were relatively low and stable.

Remeasured results of consultant D (5 buildings with 171 units (treated as 5 projects); 5 buildings with 115 units; 1 building with 91 units (second-time renovation); and 1 building with 91 units (second-time renovation))
Consultant D has provided data on first-time renovations (D-1 to 6) and on second-time renovations (D-7 and 8). These were analysed separately.

Looking at the results on the first-time renovations, the rate of cost rise due to quantity increase was 3.9%, and the rate of cost fall due to quantity decrease was 2.9%, both showing stability. However, the rate of cost rise due to additional work and the rate of cost fall due to deleted work were both high at 14.2% and 11.7%, respectively. These high rates of change were ultimately offset by each other.

Focusing on the second-time renovations (consultant D did not take part in their first-time projects), the remeasured renovation costs decreased from the initial contractual costs by 1.9%. This result reflects a high rate of cost fall due to quantity decrease of 6.3%, while the rate of cost rise due to quantity increase was 2.7%. The rate of cost rise due to additional work was 5.1%, and the rate of cost fall due to deleted work was 3.4%. Compared to the first-time renovations, the rate of cost fall due to quantity decrease was high in the second-time renovations. It also appears that renovation history helped them reduce the occurrence of unexpected events.

Cost fall due to quantity decrease and cost rise due to quantity increase (Figure 1)
Figure 1 shows the ratios of cost rise due to quantity increase and those of cost fall due to quantity decrease for each consultant. There are differences among the consultants. The results of consultant D were within the range of plus or minus 5% both for cost rise and fall. As for consultant B, the rates of cost fall were higher than those of cost rise. On the other hand, consultant A shows higher cost-rise rates and lower cost-fall rates. The results of consultant C were divided into those within the range of plus or minus 5% and those showing high rates of cost rise, indicating difference depending on housing projects.

Cost rise due to additional work and cost rise due to quantity increase (Figure 2)
Each consultant knows that the rates of cost rise due to additional work were larger than those of cost change due to quantity change. The consultants tried to offset cost rise from additional work by cost fall from deleted work, but ending up in a cost increase. Cost rises of over 10% or 20% are seen in consultant B and D (first-time renovation). However, there was much variation among the projects of each consultant.

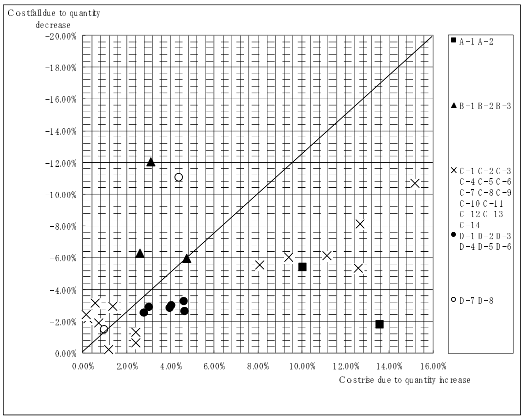


Figure 1: Cost fall due to quantity decrease (Y-axis) and cost rise due to quantity increase (X-axis)

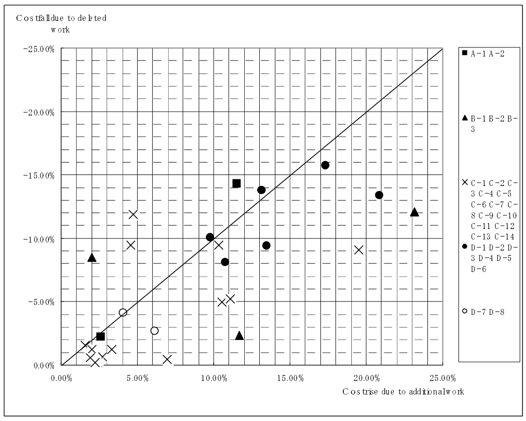


Figure 3: Cost rise due to additional work (X-axis) and cost fall due to deleted work (Y-axis)

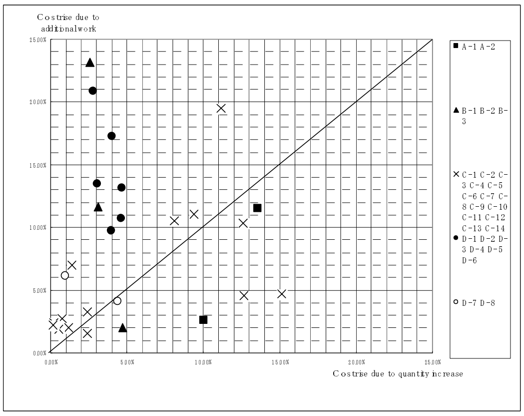


Figure 2: Cost rise due to additional work (Y-axis) and cost rise due to quantity increase (X-axis)

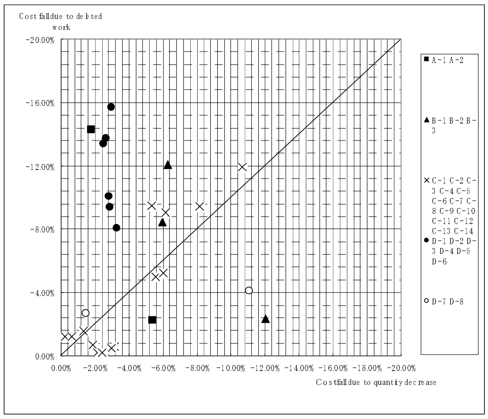


Figure 4: Cost fall due to deleted work (Y-axis) and cost fall due to quantity decrease (X-axis)

CONCLUSION

Renovation projects on housing complexes have uncertain factors at the time of conclusion of contracts, and there is a high possibility of designs and specifications being revised after actual work has started. Therefore, it is necessary to reconsider the forms of contracts, and to include provisional costs and contingencies as with remeasurement contracts.

In order to cope with cost fluctuations, the surveyed renovation consultants, who employ remeasurement contracts, request ordering parties to prepare contingencies ranging from 5% to 10% of the total project costs based on a current experience.

It has also been found that the difference between initial provisional cost and remeasured cost was managed to fall within the amount of contingency.

As for the cost increase and decrease of each renovation item, the difference of each project is large. Especially, the difference of the repair of the outside wall finish (mortar and tile) is large.

However, patterns of the cost change resulting from quantity change varied depending on consultants. The increase tended to be by consultant A and C, which set tentative amounts based on visual inspections and their experience. On the other hand, consultant B's was reduced due to its initial close inspections.

There were also differences depending on whether this was a first- or second-time renovation project.

Cost rises due to additional work had a great influence on renovation costs, and such cost rise depended more on projects than on consultants. It is important to present provisional costs that would correspond to possible additional work.

One method to enhance the accuracy of provisional quantities is to spend money on conducting rigid preliminary inspections. However, some consultants indicated the limitations of preliminary inspections and it is unlikely that this method will gain general acceptance. In these circumstances, the accuracy of quantity estimations needs to be improved through the development of a database of quantity remeasurement reports.

Moreover, although it doesn't make comparative study at present, it seems there is more research based on BQ contract accumulation in countries other than Japan. This is something I will consider to undertake in the future.

REFERENCES

The Japan Institute of Architects (1998) *Practical Specifications for Renovation Work on Housing Complexes and Explanations*. Tesuado Publishing.

Kazuyoshi Endo (1997) Construction Contracts in Stock Era. *BELCA NEWS*, **46**, 36–41.

Association to Study Measures to Promote the Introduction of CM-Method (2002) *Survey Reports on Measures to Promote the Introduction of CM-Method*, Dec.

Tetsukazu Akiyama and Eiji Seki (2003) *Research on the Support for the Ensuring of Quality of Housing-Complex Renovation Work*, Annual Report No. 29 of Housing Research Foundation, Mar.

Tetsukazu Akiyama (2003) *Design and Cost*. "Construction Cost Research" Research Institute on Building Cost, 12-14, July.

Eiji Seki (2004) *Study on Renovations on Condominiums and Quality Preservation on a Long-Term Basis*, unpublished doctoral thesis, Mar.

Eiji Seki and Tetsukazu Akiyama (2002) Research on Quality of Renovation Work on Condominiums. *In:* collected papers from the *18th Building Production Symposium*, July.

Tetsukazu Akiyama and Eiji Seki (2004) Research on Uncertainty of Renovation Projects on Condominiums – Focusing on Specifications and Bill of Quantities Reports. *In:* collected papers from the *20th Building Production Symposium*, July.

558 SITE-MEETING MINUTES FROM 20 COMPARABLE PROJECTS – A QUASI-EXPERIMENTAL EVALUATION OF PARTNERING

Johan Nyström[1]

Building and Real Estate Economics, Royal Institute of Technology, Drottning Kristinasväg 30, 100 44 Stockholm, Sweden

558 site-meeting minutes from 20 publicly procured projects have been analysed to extract differences between partnering and non-partnering projects concerning cost and quality, where time delays, the amount of disputes, financial outcome and contract flexibility have been used as indicators. In order to find the unique effect of partnering and control for other affecting variables, a quasi-experimental evaluation has been carried out. This approach strives to match partnering projects with identical non-partnering projects on every relevant variable except partnering. By trying to provide more tangible data and an improved structure, this study can be seen as reaction to the criticisms of earlier empirical evaluations. The paper has pushed the frontier for partnering evaluations forward concerning method and data. No systematic or general trends can be seen in the material. The result casts a shadow over the positive results from earlier evaluations and suggests that the main contribution of partnering might lie in its intangible effects. Partnering can be seen as something that is intended to improve the general perception of a construction industry, a declaration of a will to change.

Keywords: evaluation, partnering, quasi-experiment, research methods.

INTRODUCTION

The concept of partnering in the construction industry has, since the Latham report (1994), been a topic of discussion both in the business press and in academic circles. Evaluations of the use of partnering most often indicate good outcomes concerning cost, quality and time. The majority of these studies are made in a similar manner, and a number of authors have questioned the quality and neutrality of the evaluations (e.g. Green 1999; Bresnen and Marshall 2000; Bresnen 2007). Based on this criticism, Nyström (2006) set out to improve the method in which partnering is evaluated. The study concludes on some fundamental shortcomings in the current bulk of partnering evaluations. Case studies cannot make statistical generalizations, questionnaire results have a problem with the respondents' self-justification and a comparative analysis is needed for drawing conclusions. The study does not dismiss case studies and questionnaire as scientific tools but makes an argument that the quasi-experiment is more suitable for evaluating partnering. Moreover, the marginal benefit of a quasi-experimental study should be high since there are no conducted before. The data consist of over 558 site-meeting minutes from 20 projects also including tendering documents, contracts, reviews and economic outcome.

[1] johan.nystrom@infra.kth.se

THE QUASI EXPERIMENT

The classical experiment takes a sample of people/objects and then randomly divides them into two groups. One group get some sort of treatment (treatment group) but the other does not (control group) and conclusions can be drawn whether the treatment caused an effect. This is according to Rossi (1989) the most prominent way of doing evaluation. Often when wanting to evaluate some social programme or policy the evaluator does not have the privilege of randomly dividing groups to compare. Instead the treatment group is given, as it appears “naturally” in society. Under such circumstances, Rossi (1989) suggests that the quasi-experiment is suitable. The problem is then to find the best possible match to the predetermined treatment group concerning all relevant independent variables except the one to study. The difference in definition between an experiment and a quasi-experiment is that the latter uses matching instead of random sampling when attaining the control and treatment groups (Vedung 1998). The partnering projects in this study were given, which entailed a quasi-experimental design of the evaluation in order to satisfy the conditions stated in Nyström (2006).

DATA COLLECTION

The list of partnering projects analysed in this study was taken from Nyström (2005a), in which the tendering stage of 18 partnering projects were studied. The number of partnering projects was extended to 22 through contacts with a number a people in the industry, and it is likely that most Swedish publicly procured partnering projects during recent years in the construction industry have been investigated. However, twelve of these projects had to be excluded for the following reasons: three were not completed; in two cases, it was not possible to find a similar non-partnering project; and in seven cases, enough data could not be provided. With 10 partnering projects, the process of finding them comparable non-partnering projects started. This was done by contacting well-informed people, searching the Internet and going through literature. The searching procedure avoided asking the mangers of the partnering projects directly in order to avoid a biased selection. This was successfully avoided in all but two matches. Tendering documents for all projects were collected and studied concerning the matching variables (see below) in order to control for the partnering and the non-partnering projects being comparable. The strategy was to focus on attaining site-meeting minutes, which gives a good picture of how the projects progresses. Site-meeting minutes could also be seen as an easier way of getting representative data compared to interviews and questionnaires. Contracts, economical outcomes, different forms of outcome reports, e.g. final inspections and reviews, were also gathered. In closure, the data gathering focused on collecting site-meeting minutes, but used all interesting material that could be found. All parties involved were contacted and no energy was spared in order to get relevant information on each project.

THE DEFINTION OF PARTNERING AND MATCHING VARIABLES

A critical question in any evaluation of partnering is to identify what differentiates partnering projects from non-partnering projects. Many evaluations are problematic because they do not identify partnering projects on ex ante information. Identifying partnering ex post makes it possible for a partnering enthusiast to wave off negative results from the evaluation by arguing that the project studied were not “proper partnering”. As the project was not a success, it could not have been a real partnering project. To avoid this problem, a partnering project in this study was defined as a project where partnering/partnership/collaboration or something similar is mentioned in the tendering documents. Adopting this approach creates another problem of the partnering projects not being carried out differently than traditional projects, i.e. not incorporating partnering components. The conditions in the tendering might not have been followed. This will be controlled for when getting information about the projects and in the analysis the projects will be grouped in relation to the partnering flower (Nyström 2005b). Partnering is here seen as a “thing” rather than a discourse, which is too vague and imprecise in order to base the definition on ex ante information.

Matching variables

The following control variables were used to match the projects.

The Act on Public Procurement

All clients in this study are publicly owned entities, which are the Swedish Road Administration (SRA), the Swedish Rail Administration (Banverket), municipalities and publicly owned housing companies. These entities are subject to the act of public procurement entailing that all projects in this study were publicly procured.

Type of project

Projects were first divided into maintenance and housing projects. The projects within the same match needed to be of the same type and involved in the same line of work. A deeper analysis concerning the type of work was also required since projects differed within these two broad categories. All of the matches also took into account size, measured both in physical size (e.g. length of roads, number of apartments etc.) and in monetary terms.

Type of specifications

The Swedish construction industry has two kinds of generic conditions facilitating contracting. ABT and AB support design-and-build-contracts and prescriptive contracting, respectively. These conditions can be referred to in the contract, which means that a number of things are regulated automatically. These general contract specifications are developed and accepted by both clients and contractors organizations.

Type of contract

It is safe to say that monetary incentives have an effect on the outcome of projects. There are generally three different contract forms; cost plus-, fixed price- and target cost contracts. However, the payment schemes are often more complicated than these three extremes, which needs to be and was accounted for.

Organizational size

The contractor market in Sweden generally consists of four nationwide firms and small regional ones. Contractor size provides different opportunities for the projects, for example, because of financial muscles, which is why this variable needed to be controlled for. The size of the clients also provides different opportunities.

Geographical closeness

Most types of empirical studies have the problem of controlling for all relevant variables. One way of facilitating this is to choose control variables that can cover a number of circumstances that otherwise would be hard to control for. Matching projects according to geographical closeness takes care of many general variables that might affect the outcome, for example weather conditions. Geographical closeness was interpreted as being in the same Swedish region.

Summary of the matching
The above variables could not be fulfilled in all matches, with contract type being the most important problem. Most partnering projects used some version of a target cost contract, which was hard to find in traditional projects and could not be controlled for. This means that possible conclusion of partnering's effect on outcome cannot be separated from the effect of the target cost contract. In closure, it can be said that 10 matches were found where both twin projects were publicly procured according to the Swedish public procurement act, consisted of the same type of work, had the same type of specifications, were comparable in size and had the comparable clients and contractors. The matching had shortcomings but the database provides an improved foundation to evaluate partnering.

ARE THERE ANY DIFFERENCES BETWEEN PARTNERING AND NON-PARTNERING?

This section will give data on the twin projects concerning the matching variables from above and provide the conclusion of each comparison. The analysis of the material focused on the variables time, contract flexibility, disputes, indicators of quality and economic outcome (see Nyström (2006) for more detailed description). Most projects did provide the financial outcome but since organizations define and report costs in different ways it was hard to make an exact comparison. The strategy was to remove everything but the contractors' invoices to the client for building/maintenance and for additional work in order to make a comparison. This excludes government subsides, overheads, insurance, land cost, etc. Since the material is heterogeneous, the analysis of each match will start by describing the data that the analysis was based on and then provide some information on the matching variables to conclude with the outcome of the comparison. Information on the matching variables will be cut down to a minimum due to lack of space.

Match 1, road maintenance

The material from the two projects consists of 77 minutes from site meetings, where 34 were from the partnering project. The client's project manager, who was the same person for both projects, had written both sets of minutes. This meant that the meetings were structured in a similar way for both projects, with paragraphs discussing how the work developed, keeping track of the budget and quality matters. Tendering documents, the contract and the economic outcome were collected for both projects. Two internal reviews were gathered and two partnering meetings were attended. In 1992, the SRA separated their production unit and exposed them to private competition. Both contractors in this match belong to the SRA production unit but had to compete with private companies for the contracts. The projects are geographically adjacent and have the same project manager from the client. The contract in the partnering project was three years long with an option for another three years (henceforth 3+3), while the non-partnering contract was for six years. A fixed price was used in the non-partnering project, while the partnering project had a target cost with incentives. The analysed material indicates that there were more constructive type of dialogues concerning improvements in the partnering project. These discussions led to some tests of new ideas with positive results. The partnering project showed signs of flexibility with contract amounts renegotiated in both directions. It can be seen that none of the contractors delivered an exceptionally poor level of quality, which would have been indicated by the site meeting minutes. The economic outcome was better in the partnering project and the general conclusion from the analysed material concerning this comparison was that the outcome is in favour of the partnering project.

Match 2, road maintenance
The data in this comparison consist of the minutes of 79 site meetings; 32 from the partnering project. Contracting documents, the contract and economic outcome were also gathered for both projects. The author attended one partnering meeting. Just like the above match, these projects are geographically adjacent and have the same contractor companies, which formally belong to the same organization. The partnering was for three years, while the non-partnering project had a 4+2 contract. A target cost was used for the partnering project and a fixed price for the non-partnering project. Despite the fact that there was more frequent discussion of improvements in the partnering project, this did not lead to more recorded efficiency-enhancing activities. Both projects indicated a willingness to try new ideas and showed flexibility in their way of working. No recorded problems with quality can be observed in either of the projects. Based on the economic outcome and the good communication with the public, the general conclusion on the projects is somewhat in favour of the partnering project.

Match 3, rail maintenance
The analysed material consists of 57 meeting minutes, where 18 were from the partnering project. Both projects also provided the contracting documents and the economic outcome. However, the economic outcome was not detailed enough to make a comparative analysis meaningful. A review was also collected from the partnering project and one partnering meeting was attended. Banverket has the same type of arrangement as SRA with a separated production unit competing on the market for maintenance contracts. The partnering contractor in this match is belongs to Banverket but the non-partnering contractor is a private company. Both projects are geographically close and had comparable type and amount of traffic. A target cost was used for the partnering project and a fixed price for the non-partnering project. The partnering contract was for 5+2 years, while the non-partnering project had a 3+1 contract. In both projects, there was a good relationship between the parties. However, the analysed material revealed that there were fewer disputes in the non-partnering project and all discussions in that case could be handled at the project level. There were more new initiatives taken in the non-partnering project, e.g. discussions with the snowmobile club and the idea of a special budget for preventive maintenance. All variables examined were in favour of the non-partnering project.

Match 4, rail maintenance
The data analysed for this comparison come from the minutes of 41 site meetings; 14 from the partnering project. Tendering documents and the contract were also collected for both projects. The matching variable of geographically closeness could not be satisfied here. More weight were put getting comparable projects concerning type and amount of traffic. The partnering contractor was a private company and Banverket's production unit won the tendering for the non-partnering project. A target cost was used for the partnering project and a fixed price for the non-partnering project. The partnering contract was for 5+2 years, while the non-partnering project had a 3+2 contract. Both projects put great effort into developing the fundamental routines,

which could explain why there was a lack of tests of new ideas and innovations. A difference between the projects can be seen concerning the way questions were solved. The non-partnering project arrived at solutions by discussion, which in most cases, however, was unconstructive. In the partnering project, the dialogue was led by the experienced client. Despite this, there were no major problems in the partnering project and the removal of defects were substantially better, which concludes in favour of the partnering project.

Match 5, road maintenance

The data consist of the minutes of 50 site meetings; 37 from the partnering project. Both projects have also provided tendering documents and the contract. The client in the partnering project wrote a summary of each year, two of those were collected as well as a comprehensive report of the first four years of the project. An external review of the partnering project was also included. The projects are both located in the suburbs of Stockholm and handled the same kind of traffic. Park maintenance was also included in the partnering contract but to a small part. There was a difference concerning specifications in this match. This problem is not so severe concerning maintenance and both projects were based on performance contracting, which entailed contractual deviations from the general specifications. Both projects had a fixed price and the partnering project had a contract for 5+2 years, while the non-partnering project had a 2+2 contract. The lack of informative material in the non-partnering project complicates this comparison. However, the material for the non-partnering project did not reveal any disputes, which were current in the partnering project, according to the site meeting minutes. The problems in the partnering project were mainly related to administrative issues while the actual maintenance ran smoothly, with a fulfilled level of quality. The analysed material reveals more problems in the partnering project.

Match 6, municipality house maintenance

The material analysed for the partnering project consists of the minutes of 106 site meetings, a questionnaire on customer satisfaction and an external review. The minutes of 15 site meetings and a manuscript from an in-depth interview with the project manager were provided from the non-partnering project. The projects in this match are geographically separated but are both situated in average sized cities in Sweden. Both projects had a fixed price and the partnering project had a contract for 5+2 years, while the non-partnering project had a 3+2 contract. Both projects were procured for the first time and both contractors had problems fulfilling their obligations in the first year of the contract. An explanation might be found in the large extent of performance contracting. This gives the contractor many degrees of freedom, which they might not have been ready for. The problem in the partnering project was mainly a lack of fulfilment of some of the administrative duties, but there are no indications of the contractor not performing their practical duties. There were more severe problems in the non-partnering project, with the contractor not fulfilling administrative duties and performing the maintenance poorly. The quality level in the non-partnering project, by all indications, must be interpreted as being lower. Despite problems in both projects, the partnering project emerges as having the least amount of problems.

Match 7, water supply and sewage maintenance

The data consist of the tendering documents and the contract for both projects. The minutes of 54 site meetings were gathered, with 44 from the partnering project. Two external reviews were provided from the partnering project. An interview was also conducted with an employee of the contractor that had experience of both projects. The projects are both located in the suburbs of Stockholm and the contractor is the same firm for both projects. A cost plus contract was used in the non-partnering project and a fixed price in the partnering project. The partnering project had a contract for 9+2 years, while the non-partnering project had a 3+2 contract. Analysing the material produces a picture of more problems in the partnering project, with the big dispute on how to interpret the contract affecting the relationship in the project. The non-partnering project seems to run well without any major problems, which might be explained by the attention to clarity between the parties and a better-defined contract than in the partnering project. Despite that, the partnering project improved over time, mainly with the settlement of routines. However, the result of the comparison concerning disputes and flexibility points to an advantage of the non-partnering project.

Match 8, road maintenance

The material analysed in this match consists of the minutes of 39 site meetings. Twenty-nine of them are from the partnering project, which also provided tendering documents, the final inspection report and three external reports. Tendering documents, the contract and a review with a follow-up meeting were collected from the non-partnering project. The municipalities in this match are geographically separated. Tendering and the day-to-day activities in the partnering are not handled directly by the municipality but by a company that is to a 100% owned by the municipality. The difference between the two client divisions is not big and does not interfere with this matching. A cost plus contract was used in the non-partnering project and a fixed price in the partnering project. The partnering project had a contract for 5+2 years, while the non-partnering project had a 3+2 contract. The analysed material indicated some fundamental problems in the non-partnering project. These problems were, however, approached by both parties with serious intentions of change. Discussions on improvements in efficiency and a curiosity about new ideas were more frequent in the partnering project, but not many actual improvements were recorded. The partnering project also indicated more flexibility in the contract. Fundamental problems in the non-partnering project, which could not be found in the partnering project, conclude this match in favour of the partnering project.

Match 9, flats

The data analysed consists of minutes of 79 site meetings, with 68 from the partnering project. Both projects have also provided tendering documents, economic outcome and the final inspection report. These projects are geographically separated. Evaluation of the tenders in the partnering project was only based on soft parameters. The tendering was only based on soft parameters and the budget was developed together since no price was delivered in the tendering process. A cost plus contract was used in the partnering project and a fixed price in the non-partnering project. Design and build contracts in comparison to prescriptive contracts are thought not to require much client involvement. The non-partnering project was an example of when this works. Client involvement went no further than reminding the contractor of logos in the shower, and the construction was done satisfactorily without much involvement on the part of the client. In comparison, the partnering project had a lot of client involvement. This has been expressed as a positive feature in reports from the project and the client-driven partnering process did actually lead to some improvements from the contractors and subcontractors. Despite different methods, both projects must be characterized as good and no significant difference can be seen concerning construction time. The number of faults in the final inspection and economic outcome, however, are decisive in favour of the non-partnering project.

Match 10, flats

The analysed material consists of the minutes of 26 site meetings, with 15 from the partnering project. Both projects provided the final inspection and the economic outcome. A review and minutes from the client's board meetings concerning the partnering project were also included in the analysed material. The projects in this match can derived to the same region of Sweden. A cost plus contract was used in the partnering project and a fixed price in the non-partnering project. None of the projects ran into any major problems. The big difference concerned client involvement in the partnering project, which could be interpreted as a disturbance for the contractor or as an effective monitoring mechanism, e.g. about the choice of materials. Given the comprehensive data it is most likely that client involvement had negative effects by delaying decisions, especially since the client already had a chance of doing this ex ante. The partnering project did not perform poorly in comparison with the non-partnering project, however – both had the tenants moving in on time and for a similar cost. The non-partnering project did give some indications of more flexibility, with suggestions being adapted more easily than in the partnering project. There are indications of the partnering project being cheaper and faster, but the non-partnering project seemed to be more flexible. No difference can be concluded regarding quality. Hence, no clear difference in outcome can be observed in this match.

ANALYSIS AND DISCUSSION

The comparisons of the projects presented above conclude in favour of the partnering project in five out of the 10 matches, as seen in Table 1.

Table 1: Summary of evaluations per match

	Overall	Quality	Lowest cost	Contract flexibility	Avoidance of disputes	Time*
Match 1	Partnering	No difference	Partnering	Partnering	No difference	-
Match 2	Partnering	No difference	Partnering	No difference	No difference	-
Match 3	Non partnering	No difference	-	Non-partnering	Non-partnering	-
Match 4	Partnering	Partnering	-	No difference	Partnering	-
Match 5	Non partnering	No difference	-	No difference	Non-partnering	-
Match 6	Partnering	Partnering	-	No difference	Partnering	-
Match 7	Non partnering	No difference	-	Non-partnering	Non-partnering	-
Match 8	Partnering	Partnering	-	Partnering	Partnering	-
Match 9	Non partnering	Non-partnering	Non-partnering	Partnering	No difference	No-difference
Match 10	No difference	No difference	No difference	No difference	No difference	Partnering

* not applicable for maintenance

- indicates no data available

No general trend can be seen in the outcome variables above. A distinction can, however, be made among the matches based on how partnering is interpreted and implemented in the specific project. Identifying partnering projects from what is stated in the tendering documents avoids the problem of only focusing on successful partnering projects, but it entails the potential dilemma of evaluating "partnering projects" carried out without the usual partnering components. A solution to this problem is to use the partnering flower from Nyström (2005b) to ascertain that the "partnering" projects evaluated really included partnering components. In order to be classified as a "real" partnering project, a project should then at least include common goals. Examining the partnering project in the matches above, it can be concluded that although five projects mentioned partnering in the tendering documents they did not really include the central partnering components in the actual work. Observe that this exclusion is not based on the outcome but on which variables that were actually included. Matches 1, 2, 3, 8 and 9 included common goals at least and can, given these criteria, be considered as partnering projects. Even with the focus on this more homogenous group of "real" partnering projects, no overall trends in the outcome can be seen in the material.

Discussion

A review of partnering evaluations (Nyström 2006) showed that the most frequent outcomes of partnering were improving communication, improving the relationship between parties and better quality. These effects in favour of partnering could also be found in some of the matches analysed, but not to a systematic and general extent. Nyström (2006) argues, from an economist's point of view, that cost and quality are the variables that create value. To this can be added the comments on the absences of tangible effects of partnering in Gransberg *et al*. (1999) and Beach *et al*. (2005). Another related concern is the way in which earlier studies have been conducted by providing mostly anecdotal evidence (Bresnen and Marshall 2000, Bresnen 2007). This paper has tried to fulfil the demands of these critics and pushed the frontier for partnering evaluations forward. The lack of a common systematic and general trend in the evaluation casts a shadow over the earlier evaluations due to the fact that this study was conducted with better data and with an improved method, even if the number of observations is small. Intangible effects, like more fun at the workplace, a more attractive profession, an improved picture of the construction industry, etc was deliberately neglected in favour of more tangible effects. However, a reasonable question is whether partnering has its greatest impact concerning cost and quality and other tangible effects. Partnering in the UK and Sweden emerged as a reaction to critical governmental reviews of the construction industry. An appealing idea is that partnering could be seen as something that is intended to improve the general perception of a construction industry, a declaration of a will to change. Both the clients and the contractors in the UK and Sweden have had a common interest in achieving this, in order to e.g. attract a qualified younger generation to the sector. Partnering is likely to disappear as a specific term in time and many of its components will be included in "traditional projects" and become the natural way of working.

CONCLUSIONS

In this paper, notice has been taken of the arguments put forward by critics of earlier partnering evaluations and the improved methods that have been developed in Nyström (2006). The conclusions there have been applied in this study by using a quasi-experimental approach to the evaluation of partnering. One, not very surprising, finding is that half of the projects that mentioned partnering in the tendering documents did not include partnering components during the project. Removing these projects, still no general trend concerning the outcome in terms of cost, quality, contract flexibility, avoidance of disputes or construction time can be seen. This result can be contrasted to earlier studies showing optimistic outcome of partnering based on less detailed data and with an inferior method compared to this study. The main contribution of partnering might lie in its intangible effects, where the concept can be seen as a declaration of a will to change and improve the general perception of an unhealthy construction industry.

REFERENCES

Beach, R, Webster, M and Campbell, K M (2005) An evaluation of partnership development in the construction industry. *International Journal of Project Management,* **23**(8), 611–21.

Bresnen, M and Marshall, N (2000) Building partnerships: case studies of client-contractor collaboration in the UK construction industry. *Construction Management and Economics,* **18**(7), 819–32.

Bresnen, M (2007) Deconstructing partnering in project-based organisation: Seven pillars, seven paradoxes and seven deadly sins. *International Journal of Project Management* (forthcoming).

Gransberg, D, Dillon, W D, Reynolds, L and Boyd, J (1999) Quantitative analysis of partnered project performance. *Journal of Construction Engineering and Management*, **125**(3), 161–6.

Green, S D (1999) Partnering the propaganda of corporatism. *Journal of Construction Procurement*, **5**(2), 177–86.

Latham, M Sir (1994) *Constructing the Team: Joint Review of Procurement and Contractual Arrangements in the United Kingdom Construction Industry*. London: HMSO.

Nyström, J (2005a) *The Swedish construction industry's perception of partnering over two years – results from two questionnaires*. Licentiate Thesis, Royal Institute of Technology, Stockholm.

Nyström, J (2005b) The definition of Partnering as a Wittgenstein Family-Resemblance concept. *Construction Management and Economics*, **23**(5), 473–81.

Nyström, J (2006) The naivety of partnering assessments. *In:* D Boyd (Ed.) *22nd Annual ARCOM Conference*. UCE, Birmingham, September 2006. Reading: ARCOM.

Rossi, P (1989) *Evaluation: a systematic approach*. Newbury Park: Sage.

Stephenson, R J (1996) *Project partnering for the design and construction industry*. New York: Wiley.

Vedung (1998) *Utvärdering i politik och förvaltning*. Lund: Studentlitteratur.

Winch, G M (2000). Institutional reform in British construction: partnering and private finance. *Building Research and Information,* **28**(2), 141–55.

Wood, G and Ellis, R (2005) Main contractor experiences of partnering relationships on UK construction projects. *Construction Management and Economics,* **23**(3), 317–25.

PARTNERING ISSUES: THE EVALUATION OF LOCAL AUTHORITY ADOPTION OF PARTNERING IN SCOTLAND

Bassam Bjeirmi,[1] Paul Begg and Jonathan Scott

The Robert Gordon University, The Scott Sutherland School of Architecture and Built Environment, Garthdee Road, Aberdeen, AB107QB, UK

This paper focuses on the practical implementation of partnering arrangements within local authorities. The construction industry is the subject of ongoing criticism for poor performance on all types of construction throughout the construction process. Analysis of the construction industry highlights that historically there has been significant fragmentation and a poor record in terms of quality, waste, financial claims, safety and efficiency. Arguably, this is caused by the lack of communication throughout the construction process. This has resulted in calls for changes to the procurement methods and for the adoption of new processes that aim to improve construction performance through communication. Partnering is one such procurement method that claims to aid discourse, increase productivity, lower costs and provide stability and open accountability for each stage of the construction process. It offers an alternative to the widely used traditional procurement process. This paper investigates the issues associated with the implementation of partnering agreements within local authorities in Scotland. After discussing the reasons behind the development of partnering arrangements and the expected benefits, it presents a number of issues identified as a result of a research project into several partnering projects. These issues are prevalent during all the stages of the construction process with one of the main issues being the process of setting up the partnering arrangement including the criteria used for the selection of partners. Other issues include the role and the attributes of the partnering facilitator, the effect on project design, social training required and the role of the client and his/her quantity surveyor within the partnering arrangement. These issues have affected the success of the partnering arrangement.

Keywords: contractor selection, facilitator, partnering, project management, value management.

INTRODUCTION

Construction industry literature has been exhausted with investigative reviews and research on the state of the construction industry and its processes. The remit for the Simon report in 1944 was to produce ‘recommendations to ensure that building organization shall be so improved as to provide the best possible service to the nation while maintaining an efficient and prosperous industry’. Subsequent reports such as “Constructing the Team” by Sir Michael Latham (1994) and “Rethinking Construction” by Sir John Egan (1998) had similar remits. Investigation and analysis of the traditional methods of construction describe a process that is often fragmented, of low quality, high waste and high claims (NAO 2001). Consequently, the

[1] b.bjeirmi@rgu.ac.uk

construction industry consistently under-performs on issues such as cost, quality, value, time and function (Fisher and Green 2001).

One of the conclusions of the 1944 Simon Report was the need for ‘complete collaboration between building owner and contractor’. This is a repeating theme in subsequent reports resulting in recommendations for the adoption of new processes that, it is claimed, will improve the performance of the industry (Egan 1998). It is suggested that improved collaboration can be realized through partnering and, consequently, there has been increased interest in this form of procurement that has been seen by many as an important way of improving construction/project performance. Benefits from partnering are claimed by Sanders and Moore (1992), Abudayyeh (1994), ECI (1997), Black *et al*. (2000) and Drexler and Larson (2000) and NAO (2001). In particular, Abudayyeh (1994) notes that partnering offers a ‘win-win’ scenario for the client and contractor by “[improving] problem solving and fostering synergistic teamwork”.

There is no doubt that in certain situations partnering has been very effective in developing better working relations and in producing good quality projects, particularly in the form of strategic partnering. Alternatively, on other occasions, it has failed to be an improving factor and has produced lower value projects resulting in higher costs. This dichotomy is highlighted by Fisher and Green (2001) and is echoed by Bresnen and Marshall (2000) and Cartlidge (2002).

Public bodies are constrained by the necessity to be transparently accountable for the expenditure of taxpayers’ money (ECI 1997). Consequently, there are administrative procedures where committees approve estimates and tenders and any potential overspend during construction requires to be reported and explained. A traditional tendering system assists in meeting these criteria by avoiding commercial arrangements that might be seen to be open to possible corruption. Against such a background, it is likely that the implementation of partnering by a public body, whose procurement has historically been pursued along traditional lines, would potentially raise more issues in relation to partnering implementation than within the private sector.

Ng *et al*. (2002) refer to only two notable pieces of literature on partnering in the public sector and these suggest that, paradoxically, administrative procedures in this sector designed for accountability often work against open relationships with contractors. This can jeopardize the partnering objectives originally established for the project, which would generally emphasize open accountability.

Additionally, there is a lack of information describing the issues involved in the intricate, day-to-day management of partnering arrangements. In particular, Fisher and Green (2001) note that there is little benchmarking of the process in order to understand the relative effectiveness of different strategies.

The aim of this paper is to identify the main issues associated with the implementation of partnering arrangements within local authorities and evaluate them against the theory as determined from the literature. This will be achieved by an investigative study into a series of projects to identify issues throughout the process. Although these issues have not resulted in any formal challenging of value or accountability in any of the projects studied, they were consistently present and constitute a significant debate in relation to partnering in local authorities.

RESEARCH METHODOLOGY

After an initial literature search and a pilot study investigation, it became clear that there were a number of issues that affected partnering relationships in the local authority environment. These issues involved contractor selection procedures, training and facilitation, the effect on the quality of design, dealing with changes to the work and the roles of key parties. A series of interviews were then conducted to investigate how the issues affected specific projects. A cross-case analysis was then used to compare each case studied.

The data reported here is derived from the investigation of six case studies of relatively large-scale partnering projects undertaken by experienced local authority clients. Three of these projects were already completed, two were ongoing at the time of the investigation, and the last was in its early phases where negotiation to reach an Agreed Maximum Price (AMP) was still in progress. All were building projects with a high degree of complexity and ranged from 2 to18 million pounds. Seven professionals were interviewed consisting of two clients, three architects and two facilitators.

The evaluation and appraisal of the issues is based on qualitative data. In each case, a semi-structured interview based around a number of key themes was carried out with each of the team members. Interviews were conducted over a six-month period and covered all aspects of initiating and implementing the partnering projects.

All questions were open-ended questions, which allowed for further elaboration and discussions. The resultant interview transcripts were coded manually to capture data on common themes, issues, unique circumstances and events across the cases.

PROBLEMATIC ISSUES IN PROJECT PARTNERING

An analysis of all projects was carried out to identify the main issues facing project partnering and evaluate how these issues affected the partnering arrangement in local government construction projects. A total of five categories of issues were identified as follows:

- Selection of the partnering contractor.
- Partnering training.
- Pre-construction issues.
- Construction phase issues.
- Key roles.

Selection of the partnering contractor

Black *et al.* (2000) highlight a report which notes that “Partnering implies selection (of partners) on the basis of attitude to team-working, ability to innovate and to offer efficient solutions”. However, some commentators suggest that partnering does not need to rely solely on openness, good communication and teamwork to produce value but may also need an element of competition (NAO 2001). Additionally, Baxendale and Greaves (1997) argue that competition and partnering are compatible in certain circumstances.

On the other hand, Ng *et al.*’s (2002) findings state that the use of any competitive tendering arrangement was the origin for many subsequent problematic issues including the level of commitment of stakeholders to the project partnering arrangement. In the cases that he studied, the profit margin was very low and cost control during the project was difficult with regard to defending the margin. As a result, the contractors would systematically change their priorities from the project partnering arrangement to a ‘‘win–lose’’ profit protection attitude (Ng *et al*. 2002).

Further information on the selection of partners in local authority scenarios is provided by ECI (1997). This suggests that it should be based on compatibility of the partners, their experiences, reputation and past relations. Different partnering arrangements that can be used by the public sector, which are tailored to avoid contravening the anti-competitive legislation, are highlighted. Much of the literature advocates the selection of the main contractor on an analysis, which addresses both the ‘hard’ issues (for example, finance) and the ‘soft’ issues (for example, environmental considerations) (NAO 2001; OGC 2003).

However, local authorities must justify expenditure of taxpayer’s money, which means that they must open up construction work to competitive tender on a project-by-project basis and ensure that the main contractor is bound by contract. This does not inherently encourage long-term relationships as advocated by CIC (2005). Local authorities can also be restricted by EC anti-competitive rules. The result is that the extent to which they can use one contractor, and therefore partnering in its pure form, on a series of projects without intervening competition, is limited.

In the cases studied, a selection process had been designed which ensures that the necessary transparency is retained. The contractors who initially respond to an advertisement inviting interest are required to complete questionnaires on commercial standing, specific experience and business methods, with the latter specifically relating to attitudes to partnering. The form is required to comply with EU rules for projects over £3.6 million. A small number of contractors then continue to the next stage of the selection process.

This second stage is based on a selection interview model developed by the Scottish Executive (2004) where the contractor answers questions that are weighted in terms of price and quality. These weightings can be adjusted as appropriate but were generally 60/40 in relation to price/quality respectively in the cases studied (price is based on the contractor’s on-costs submitted for the prime costs of construction). Each contractor’s answers are scored by a selection panel, which is made up of client and consultant team representatives. The scores are analysed by software that rates each contractor, resulting in a preferred contractor. The process retains transparency and provides a degree of competition on on-cost, but not on the prime cost of the work.

The third stage of the process is negotiation to agree the Agreed Maximum Price (AMP). This stage is potentially adversarial since it involves costing the work to set this price. In the absence of significant changes to the project, the contractor is paid on a cost plus basis until this maximum is reached, but not beyond. The contractor and client fulfil the formal contractual requirements by concluding a JCT Prime Cost Contract with sharing arrangements for savings.

There is an issue here as to whether this is partnering in the true sense, as agreeing the AMP has the potential to become an adversarial process that does not seem to encourage the trust and confidence that, the literature emphasizes, is required.

Furthermore, the AMP depends to a substantial degree on subcontractors and suppliers’ quotations. This means that the competitive element has effectively been moved down the supply chain to be managed by the main contractor. This has some similarities to management contracting where the management contractor receives a percentage fee from a client for pre-construction advice services and then for managing works contractors on site. Is there a necessity, therefore, to spend time and money on the complicated contractor selection process, training, the provision of a facilitator, negotiations, etc., when the competitive selection of a management contractor might be more appropriate?

In some situations, the selection process is not as formal as that described above and ranges from negotiations with a number of contractors over issues of cost and partnering attitudes, to the direct appointment of a known contractor based on historical performance where time is a critical constraint. Whilst, as Cartlidge (2002) highlights, this indicates that partnering is an approach that is flexible to suit specific circumstances, it also raises issues of transparency and accountability.

Partnering training

Cartlidge (2002) notes that trust is not found in abundance in the construction industry but it is crucial within and between partnering organizations for the process to work (ECI 1997). NAO (2001) offers a number of practical case studies, perhaps over emphasizing the positive aspects of partnering, but nevertheless emphasizing the need for social training for staff. All the literature states that partnering is a collaborative agreement based on the need for communication and trust. In an industry where this is not prevalent (Latham 1994; Egan 1998), this requires training. NAO (2001) and ECI (1997) suggest training methods that start with the client but should cover all members involved in partnering. Training workshops are essential and should be used throughout the project. These should focus both on teamwork, communication and trust and also on the practical needs of construction projects, such as conflict resolution and the need for measurement of progress (ECI 1997; Critchlow 1998). The theory is that over time trust will build up between parties, particularly with strategic partnering but also with project partnering. Bresnen and Marshall (2000) caution that to suggest partnering will change attitude in the construction industry, however, is too simplistic.

The training in the cases studied involved a single generic workshop for the Architectural Services Department and a few invited contractors that took place around ten years ago. It was organized as a result of the Latham recommendations and was mainly an information session on the principles of partnering and its benefits. Beyond this, there have been no formal training sessions. Facilitators had not received any specific training. On individual projects, a partnering workshop is held after agreement of the AMP and all the parties, including the client, attend this. There is a case for partnering workshops prior to agreeing the AMP since this is a period of negotiation that has the potential to become adversarial. However, there is an issue with the fact that the contractor has not been formally appointed prior to agreeing the AMP and therefore an event that directly implies that he has been appointed is problematic.

The training in the projects studied did not appear to continue after the initial workshop and the important position of facilitator seemed to be neglected in relation to training. In general, training did not seem to comply with the recommendations from the theory. Organizations need to use existing staff and all the participants in the above cases had extensive experience of traditional, adversarial project management. There is an important issue, therefore, concerning how the necessary attitudes for dealing with the traditional adversarial system of project administration could be transformed into attitudes appropriate for partnering with a single workshop.

Pre-construction issues

In 1962, the Emmerson Report into the construction industry advised that 'in no other important industry is the responsibility for design so far removed from the responsibility for production'. All the literature suggests that there will be increased quality in the overall design of a project that uses partnering. This stems from the early integration of the design process into the partnering arrangement, ensuring that design is not a separate exercise done in isolation. Fisher and Green (2001) suggest that partnering leads to better innovation in particular. This stems from the input from the various partners into the assessment of the design, particularly in relation to buildability, during the early stages of the process. This minimizes design changes during the construction of the project, which can lead to significant cost increases (NAO 2001). Cartlidge (2002) emphasizes that partnering increases the amount, reliability and speed of information that can inform a design thereby avoiding changes later in the construction phases. This is particularly the case with information from parties further down the supply chain.

ECI (1997) also notes that improved quality in the finished product results from partnering, which is achieved through quality management systems, which all the literature encourages throughout the project. However, a partnering team that is committed to a particular design should not significantly change this design but concentrate on the problem solving aspect of how to construct it. A contractor involved in a partnering scheme, therefore, should not unilaterally change whole aspects of a design on the basis of reducing risk or finance (ECI 1997).

The process of agreeing the AMP, which involves the contractor's quantity surveyor, the client and his/her quantity surveyor and the designers, raises the important and sensitive issues in relation to design. Ostensibly, the task is to ensure that the client's requirements are met within the available budget. However, clients and designers perceive that the process drives inevitably towards paying premium rates for the simplest building to construct – a box in other words. Negotiations are often carried out using costs from previous projects as a basis, but clients have the perception that where elements of the new project are different, the costs of these elements generally seem to be added to and not substituted for the previous costs. Also both designers and clients tend to feel that the pressure is on them to defend the design or to accept cost-cutting design changes, which may impair the operational effectiveness of the facility, rather than on the contractor to defend his prices. The process can become one where the contractor simply advises continually that the design is too expensive and asks for cheaper alternatives. The contractor has a perceived interest in maximizing the AMP so confidence in the system depends on careful scrutinization of costs by the client's quantity surveyor. The process can be 'tense', although it is generally without animosity, and it needs strong input from the client's quantity surveyor and the facilitator.

There is also an issue concerning the level to which the design requires to be complete by the negotiation stage. For maximum benefit, the contractor's input to the design should be at an early stage. However, this is not realistically possible before the AMP has been fixed because the contractor has not been formally appointed. The need to fix the AMP requires that there is sufficient design to do this effectively and a value of 80% complete was the quoted figure for the cases studied. Failure to do this leads to a situation where later design requirements will result in increases in the AMP and potential cost overruns. This again tends to undermine the value of partnering since improving the quality of design; meeting the budget and reducing the period required for the construction process are not necessarily mutually compatible.

There is also a perception that the quantity surveyors involved in the process of fixing the AMP are driving design decisions on the basis of finance and time, with the result that the designer's authority is being reduced without diminishing his/her responsibility. The perceived necessity for speed can lead to poorly thought-out design decisions, which cause consequential problems and are therefore not necessarily more cost-effective in the long run.

There were clearly significant and sensitive issues in the pre-construction phases of the projects studied which do not sit comfortably with the theory of partnering, particularly in relation to design and the control of cost.

Construction phase issues

The partnering literature focuses on the selection phase of construction, which is admittedly the key area, being the foundation of any partnering arrangement. The ECI (1997) explains, however, that after the selection process is completed it is important to keep the process running. The OGC (2003) adds that all methods of communication, risks and evaluation of work during construction should be assigned prior to construction beginning.

Egan (1998) noted that the lack of quantitative information during construction was a major factor that affected the success of future projects. Workshops should be held by the facilitator regularly to keep up to date on the performance of the project in relation to the objectives agreed to prior to the start of construction in order to show whether improvements could be made and to meet to avoid any disputes. During the construction process, all members are encouraged to be honest and forthright with any issues to avoid future conflict (ECI 1997). These issues should be summarized in a monthly performance evaluation report.

The NAO (2001) highlight that the construction phase is essential to the success of a project and the appropriate project management framework is required. This, again, needs to be clearly set out prior to the commencement of construction (NAO 2001). The lack of clear roles and responsibilities in a partnering arrangement could lead to confusion and projects being late or over budget (NAO 2001).

In general, clients perceived that there were fewer problems with the practical side of construction in partnering projects and that those which did arise were easier to resolve. Quality was perceived to be better with respect to meeting the client's requirements but there were still issues with respect to budget control, programming, risks, financial responsibility for design/specification changes and use of contingency allowances.

It must be emphasized that the AMP is not a fixed sum. Because the design is not complete when the AMP is agreed and ideas are still being developed as the project proceeds, the AMP can change. There is a clear perception with clients and designers that risk generally lies with the client with the result that the AMP always increases and the project programme is always extended. There is an issue concerning how this integrates with the spirit of partnering where the emphasis should be on the parties to find solutions jointly to minimize cost.

There is also an issue with defining whether changes to the project or the occurrence of risk events should result in changes to the AMP or whether they are already included in the AMP. In terms of changes, the general rule seems to be that trivia are ignored but the definition of what constitutes 'trivia' is not clear and this leads to uncertainty on the part of the different parties, especially the client. In addition, the AMP generally includes a 5% contingency allowance. However, it is unclear whether this is to allow for risks attributable to the client, or the contractor, or both.

Overall, the view is that if the money available is enough then there will be no major problems. Latham (1993) explained that, "where the money payable is inadequate, vital trust will be absent and the project will always suffer through lack of teamwork and adversarial attitudes." Facilitators on the projects studied were of the view that there would be a major issue if a project went seriously wrong financially, and that this would inevitably lead to a protracted contractual dispute.

Key roles

Role of the facilitator

CIC (2005) states that, "once the selection panel has been assembled a coordinator should be nominated", this being the facilitator who is responsible for the smooth running of the project throughout its duration.

The facilitator should be knowledgeable about the partnering process and experienced in the field of construction. CIC (2005) notes that the facilitator is the coordinator of the workshops between the various parties involved. The ECI (1997) further note that his activity is only a passive one and that the facilitator is there only to facilitate discourse. OGC (2003) describes the facilitator as responsible for bringing the parties together and leading workshops "to set out the principles, attitudes and ideas that will characterize the arrangement". The facilitator is involved primarily after the selection of the preferred contractor although on many occasions, as was the situation in the cases studied, the facilitator can be a member of the contractor selection panel.

The role and the skills required of a facilitator was one of the major issues creating confusion among those involved in the partnering arrangement. From the facilitators' point of view, it was debatable whether he/she should be a project manager or a facilitator and they found it difficult to differentiate between these roles. Neither of the facilitators interviewed had received training on what the role should involve and where their authority and responsibility lies. This created confusion, not only for the facilitator, but also for the rest of the team.

Also in the cases studied, the other parties had an expectation that the facilitator would function as an independent adjudicator and were critical if this did not appear to be the case. Facilitators saw their role variously as a form of 'hands off' project manager to guide the project along or as a 'chairman of a board' who listened to everyone's views before coming to a decision on their behalf. None of these concepts of the role seems to conform to the theory. This reinforces the issue in respect of the need for training for facilitators as to the nature of their role and in the social skills required to carry it out.

ROLE OF THE CLIENT

Black *et al*. (2000) and the ECI (1997) state that one of the main factors in introducing partnering successfully is to ensure that the senior management in the client's firm is committed to the process. Egan (1998) recommends more involvement from the client, recognizing that its absence may exacerbate the misunderstandings that cause disputes. ECI (1997) suggests the role of a ‘champion’ in the client organization to ensure that each member of the staff is familiar, and is in favour of, the adoption of partnering. The Champion is not necessarily a construction professional, but will know partnering intimately and will also take part in the ‘social training’ of the partnering team members. However, it is important that the changes involved in adopting partnering are ‘deep enough’, otherwise partnering will not take root (Bresnen and Marshall 2000). In essence, the client should be more involved in the construction process in order to encourage trust between the various parties in the partnering team (NAO 2001). As has been noted, it is the client who will accrue the greatest benefit from this process and it is important, therefore, for the client to be fully conversant with forward thinking and innovative partnering procedures.

The clients in the case studies were involved in the process throughout. However, the nature of that involvement was not to the extent suggested as desirable by the literature. In the pre-AMP phase, the clients’ main aim was to ensure that design changes did not have adverse operational consequences, e.g. changes to heating systems, security systems, etc. During the construction phase, the client attended the partnering meetings for the same reason and to be familiar with project progress and cost. However, beyond this, the management of the process was conducted by the facilitator and the professional services. There is an issue here in relation to the extent of client involvement and the possibility of the facilitator being appointed by the client, although there were reservations that the client would not have sufficient technical knowledge or experience of the construction process to fulfil this role.

ROLE OF THE CLIENT’S QUANTITY SURVEYOR

The role of the client’s quantity surveyor in relation to value for money became apparent as an issue within the partnering arrangements studied. In traditional contracting, the bill of quantities is a form of assurance to the client that a certain level of value is being achieved. With partnering, the early involvement of the contractor means that the project will not be fully billed and therefore the negotiation of the AMP takes place without complete information, thereby creating additional risk. Theoretically, the contractor’s prices should be transparent and the client’s quantity surveyor should be able to trust them. Nevertheless, there was a perception by clients and designers that this trust could be misplaced and that the client’s quantity surveyor should question the contractor’s prices more thoroughly to ensure value for money. There is an issue about the extent to which this may undermine the spirit of partnering, however.

CONCLUSIONS AND RECOMMENDATIONS

This paper has investigated the issues associated with the implementation of partnering agreements within local authorities in Scotland. Ultimately, the objective must be to have satisfied clients and in all the cases studied clients considered that partnering was beneficial, particularly on difficult projects. Practical problems during the construction phase are easier to solve and the ability to finalize the costs quickly on completion is particularly welcome within the local authority environment. It is also possible to moderate potentially higher prices when the construction sector is busy. Furthermore, the construction phase of projects is also generally perceived as better. However, there are still substantial issues with the form of partnering adopted which, if not addressed, may be sufficient to result in it falling from favour. These issues relate predominantly to financial arrangements, design and training.

The negotiation of the AMP had the clear potential to undermine the spirit of partnering and this was closely connected with the perception by clients and designers that the quality of design would be eroded unless they took a firm stance at this stage. Again, this does not seem to correspond with the collaborative philosophy of partnering, but accountability constraints on government bodies need to be considered. Once the AMP has been agreed, there is a lack of clarity as to the precise extent of what is included in it and when a change to the project should result in a change to the AMP. Clients have the clear perception that they are carrying all of the financial risk. Nevertheless, they are positive about the value of partnering in general terms but are less so about the control of the cost element. In particular, it is difficult to reconcile the role of the client's quantity surveyor during negotiation of the AMP with the philosophy of partnering. Partnering should be a collaboration and prices submitted by a contractor should be transparent. However, there is a perception that a lack of in-depth examination of these prices may result in reduced cost control.

There is a lack of ongoing training for all parties and training for the important role of facilitator is absent. This is a particularly important issue because the facilitator has little real power and depends on social skills to achieve results.

Whilst the clients are involved throughout the process their role tends to be to ensure that design changes do not impair the operational effectiveness of the finished project and to monitor overall cost. There is a debate around the issue of clients adopting a greater leadership role in the partnering process to the extent of providing a 'partnering champion' or even taking on the role of facilitator.

Ultimately, there is a question as to whether the existence of the issues identified suggests that the arrangements in the cases studied do not, in fact, amount to true partnering.

It is submitted that if partnering is to continue as a preferred procurement route then consideration should be given to abandoning payment of the contractor by means of a fixed AMP. A true partnering philosophy of collaboration to achieve best value should be followed. Significant training would be required to achieve this. Alternatively, if the constraints on the local authority do not allow full partnering, then consideration could be given to using a form of management contracting. This would allow useful early input from a contractor without the perceived erosion of design quality and would also maintain a transparent competitive element for the work itself.

REFERENCES

Abudayyeh, O (1994) Partnering: A team building approach to quality construction management. *J. Manage. Eng.*, **10**(6), 26–9.

Baxendale, T and Greaves, D (1997) Competitive partnering: a link between contractor and sub-contractor. *In: Procurement: A Key to Innovation*, CIB Proceedings, Publication 203, 8–21.

Black, C, Akintoye, A and Fitzgerald, E (2000) An analysis of success factors and benefits of partnering in construction. *Int. J. Proj. Manage.*, **18**(6), 423–34.

Bresnen, M and Marshall, N (2000) Partnering in Construction: A critical review of issues, problems and dilemmas. *Construction Management and Economics*, **18**, 229–37.

Cartlidge, D (2002) *New Aspects of Quantity Surveying Practice*. Oxford: Butterworth Heinemann.

Construction Industry Council (CIC) (2005) *Selecting the Team*. London: CIC.

Critchlow, J (1998) *Making Partnering Work in the Construction Industry*. Oxford: Chandos Publishing Limited.

Drexler, J A Jr and Larson, E W (2000) Partnering: why project owner-contractor relationships change. *Journal of Construction Engineering and Management*, **July/August**, 293–97.

Egan, Sir J (1998) *Rethinking Construction*. London: HMSO.

Emmerson, Sir H GCB, KVCO (1962) *Survey of Problems before the Construction Industries.* London: HMSO.

European Construction Institute (ECI) (1997) *Partnering in the Public Sector*. Loughborough: European Construction Institute.

Fisher, N and Green, S (2001) Partnering and the UK Construction Industry: The First Ten Years – A Review of the Literature. *In*: Appendix A, National Audit Office (NAO), *Modernising Construction*. London: The Stationery Office.

Latham, Sir M (1993) *Trust and Money*". Interim Report. London: HMSO, p. 15.

Latham, Sir M (1994) *Constructing the Team.* London: HMSO.

Ng, S T, Rose, T M, Mak, M and Chen, S E (2002) Problematic issues associated with project partnering – the contractor perspective. *International Journal of Project Management*, **20**, 437–49.

National Audit Office (NAO) (2001) *Modernising Construction*. London: The Stationery Office.

The Office of Government Commerce (OGC) (2003) *Effective Partnering: An Overview for Customers and Suppliers*. OGC.

Sanders, S R and Moore, M M (1992) Perceptions on partnering in the public sector. *Proj. Mgmt. J.*, **22**(4), 13–19.

Scottish Executive (2004) Client Pack: Construction Works Procurement Guidance. Available online: http://www.scotland.gov.uk/Publications/2004/06/19384/37505 (accessed 29 November 2006).

Simon, Sir E (1944) *The Placing and Management of Building Contracts*. London: HMSO.

RESOURCE ALLOCATION IN CONSTRUCTION PROJECTS: THE CONTRIBUTION OF RESOURCE-CONSTRAINED PROJECT PLANNING MODELS

Frank Schultmann[1] **and Nicole Sunke**

Chair of Business Administration, Construction Management and Economics, University of Siegen Paul-Bonatz-Str. 9-11, 57068 Siegen, Germany

This paper puts emphasis on the application of modelling for resource allocation of a variety of construction project planning problems and shows a recommended future path for the development of construction project planning. A resource classification scheme indicating the degree of planning effort for different types of resources is proposed and a taxonomy for project planning models as well as a generalized resource-constrained project scheduling model (RCPSP) are introduced as theoretical basis. Based on the RCPSP, several particularities for construction projects, of which some of them have already been addressed separately in literature for similar planning approaches, are discussed. Among these are different construction project's objectives, different constraints like the availability of construction workers and machinery, and different alternatives or modes to perform activities as discussed as time-resource and resource-resource trade-offs.

Keywords: construction planning, project management, operational research, models.

INTRODUCTION

Enterprises of the engineer-to-order sector, such as construction and engineering firms, are usually operating on a project level and are usually organized as matrix or project based organizations. Planning situations in matrix and project based organization are typically unique and differ from project to project. Additionally, more than 90 percent of these firms face a situation where they have to cope with more than one project at a time (Payne 1995: 163) competing for limited resources. The performance of a project, here understood as the adherence to delivery dates and budget as well as stakeholder satisfaction, is significantly influenced by the quality of the project management. Project management comprises the conception, definition and planning of a project as well as its execution and termination. Project planning is also described as project structuring, which consists of project scheduling and resource allocation. Whereas the aim of project scheduling is to determine start and finishing dates of project activities, the objective of resource allocation is to ensure the sufficient and timely supply of usually scarce resource for project execution (Klein 1999).

The planning effort of projects rises as the complexity of the project increases. The complexity of a project is determined by, for example, the number of project participants, the number of project stakeholders, the time span of the project, the number of project activities and the diversification of the project environment and

[1] frank.schultmann@uni-siegen.de

other restricting factors, such as the regulatory framework, for instance for waste treatment in construction.

Usually, common project planning approaches such as the Critical Path Method (CPM), the Metra Potential Method (MPM), as well as the Program Evaluation and Review Technique (PERT) focussing on time oriented objectives are used in practice. Their main advantages are the explicit representation of activity relations and their easy application. Paradoxically, however, even though a lot of scheduling procedures have been developed and tested for construction purposes, the scarceness of resources is often either neglected in scheduling approaches or seen as of minor importance in initial schedule generation in practice. In addition, methods for particular project types, such as the line of balance (LOB) method for linear and repetitive projects, or simulation have been applied. Though these methods can be applied in construction project planning, their applicability is limited to a specific project type. Focussing especially on resource allocation influencing a project schedule as critical success factor for a project, quantitative planning approaches should be preferred, such as the resource-constraint project scheduling problem (RCPSP). The resource-constrained project problem does not only provide the opportunity to pursue objectives like cost minimization or resource levelling but also considers resource limitations for project execution.

As the complexity of quantitative models for practical problems exponentially rises in dependency on the number of activities and resources to be considered, an efficient resource allocation strategy has to differentiate between critical and non-critical resources for the project planning to make quantitative models applicable to real world problems.

Hence, the objective of the paper is twofold. Whereas the first aim is to develop a resource classification scheme, the second focus lies on the presentation of a future path for the development of construction project planning by discussing the opportunities of application of the RCPSP.

The remainder of the paper is thereby organized as follows: First, we give a classification and characterization of projects based on project planning problems found in practice that is followed by a suggestion on how resources can be structured according to their criticality in the project planning process in order to allocate resource more efficiently.

Secondly, we introduce a general RCPSP model for resource-constrained project scheduling as counterpart to traditional project planning models. Based on this general model we show various extensions for different problem classes. This especially addresses various project objectives as well as the choice of technologies out of a bundle of alternative to achieve best possible objective fulfilment. Finally, examples for successful applications of the RCPSP in construction are given.

CHARACTERIZATION AND CLASSIFICATION OF PROJECTS

The literature about project management holds quite a large number of definitions for the term “project”. According to Klein (1999: 3) and Slack *et al*. (1998), a project is characterized by the following elements (for detailed information see also, e.g., Shtub *et al*. 1994; Spinner 1997): objective, uniqueness, complexity, temporary, resources, uncertainty and life cycle.

In order to organize and to optimize the management of projects, project planning problems can be formulated. For the specification of project planning problems focussing on resources availabilities, we further distinguish the complexity of a project into micro and macro complexity. Whereas the micro complexity of a project describes characteristics within and between projects, the macro complexity addresses constraints at the interfaces to the project environment. For a unique description of a project, these determinants are exemplarily specified as shown in Table 1.

Table 1: Characteristics and determinants of projects

Project characteristics	**Key determinants**	**Specification**
Objective	Type of project	• Research and development project, design project, software project, construction project etc.
	Type of objective	• Time, cost, resource, environment
	Number of objectives	• Single, multiple
Complexity micro	Number of projects	• Single, multiple
	Project structure	• Repetitive, linear, complex
	Precedence constraints	• Finish-to-start, start-to-start, min-max-timelags
	Processing modes	• Single, multiple
	Set-up times	• Negligible, static, mode-sequence dependent
Complexity macro	Participants	• Shareholder: owner, bank, contractor, ... • Stakeholder: owner, bank, contractor, designer, government, interest groups, …
	Regulatory framework	• Economic, social, ecological legislation
	Conditions for operation	• Enterprise internal regulations • Industrial interventions • Project environment: space, climate, culture, ...
Temporary	Time horizon	• Determined • Non-determined
Resources	Resource type	• Renewable, non-renewable
Uncertainty	Resource availability	• Deterministic, stochastic, possibilistic
	Activity durations	• Deterministic, stochastic, possibilistic
	Precedence relations	• Deterministic, stochastic, possibilistic

The purpose of project planning is the allocation of resources to the activities of the project, such that a particular project objective is attained. Since the late 1950s, the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) have been the focus of intensive research effort and acknowledged a wide spread use by practitioners in management and control of large-scale construction projects. However, the construction industry differs significantly from other industries because of changing production sites, multiple simultaneous projects and, hence, allocation of resources from site to site. Bearing the complexity of the construction project planning problem in mind these project planning techniques cannot satisfy the specific needs of project planners in the construction industry. Even current project management software, like Microsoft Project®, Suretrak® and Primavera®, cannot fully satisfy requirements of project planners and do not always guarantee a user friendly and easy to comprehend application (Herroelen and Leus 2005: 104).

Instead, simulation or planning approaches from Operations Research, such as resource-constrained project scheduling, represent an appropriate alternative to traditional planning methods. Thereby, the choice of solution method to solve a particular resource allocation problem strongly depends on the combination of the specifications, i.e. on the type of construction project referring, for instance, to its objective, the number of projects to be planned, the resource types and availabilities as well as the time horizon and project participants. Hence, different project types can be identified for which planning strategies can be derived.

RESOURCE ALLOCATION IN CONSTRUCTION PROJECTS

Primarily in construction, resource allocation is a major topic that discusses project planning in detail. The result of project planning is a project schedule, i.e. a definition of a set of starting and finishing times of project activities under consideration of limited resource availability. A project schedule is not just a valuable instrument in communication and coordination processes with external partners in the company's inbound or outbound supply chain, but serves both the planning of project activities and a related resource assignment to each activity considering some measure of performance as well as the planning of external activities (Herroelen and Leus 2005: 107).

In the planning and resource allocation process, various objectives are considered. These objectives are usually management-driven and focus on time, costs as well as other aspects as depicted in Table 1. Common objectives in construction project management and scheduling are, for instance, the minimization of project durations under multiple resource constraints (Moselhi and Lorterapong 1993), the minimization of the total project delay (Tsai and Chiu 1996) as well as the minimization of costs of total resource consumption, including time and a levelled resource distribution (Karshenas and Haber 1990). Furthermore, objectives like maximizing the total project net present value by considering project delay penalties and early completion bonuses (Chiu and Tsai 2002) as well as finding the optimal resource selection optimizing time and cost objectives of a construction project (Burns *et al*. 1996) are pursued. Additionally, considering the case of repetitive activities, objectives might address the minimization of idle crew time (El-Rayes and Moselhi 1998). Also, project management can address the generation of a schedule-dependent site layout planning (Elbeltagi *et al*. 2001).

The achievement of the project's objectives significantly depends on the availability, the amount and the costs of resources to be allocated to projects and their corresponding activities over the project time horizon, hence the quality of the project schedule. For construction projects, these resources can be distinguished according to different criteria. In practical planning environments in the construction industry, the resources allocated usually comprise money, labour, equipment and construction materials.

For the application of quantitative planning models, the differentiation of project resources according to their renewability is necessary. Renewable resources are resources that are only available in a limited amount per period, for instance machines or workers. If resources are non-renewable, they are constrained over the whole planning horizon or project duration, e.g. budgetary constraints (Slowinski 1979: 455–6; Weglarz 1979: 522).

To reduce the complexity of the project planning problem and to provide a basis for a selection of particular resources for detailed resource planning, further classification criteria, besides the renewability, are applied. Thus, each of the resource types mentioned above can further be distinguished and evaluated according to the criteria: technology/know-how, value, mobility, supply, supply variance and procurement pattern. For instance, a patented construction technique with the enterprise holding a unique selling proposition can be considered as cost-intensive and highly specialized construction equipment. This construction equipment is characterized by a constant supply and the absence of the opportunity of third party supply, i.e. renewable resource. In contrary, concrete is a non-renewable low-mass building material with an order dependent, hence variable, quantity and is consumed (non-renewable) during the project progress.

Sophisticated resource allocation does not necessarily mean to precisely allocate all resources of a project. In order to reduce complexity of the planning procedure, it might be advisable to rank resources or their impact on the stability of the project schedule according to certain criteria. A well-established procedure for the ranking and classification of objects is the ABC/XYZ analysis known from material requirements planning. Figure 1 depicts the classification of resources into critical, non-critical, and risk-prone resources with the ABC/XYZ analysis of resource allocation.

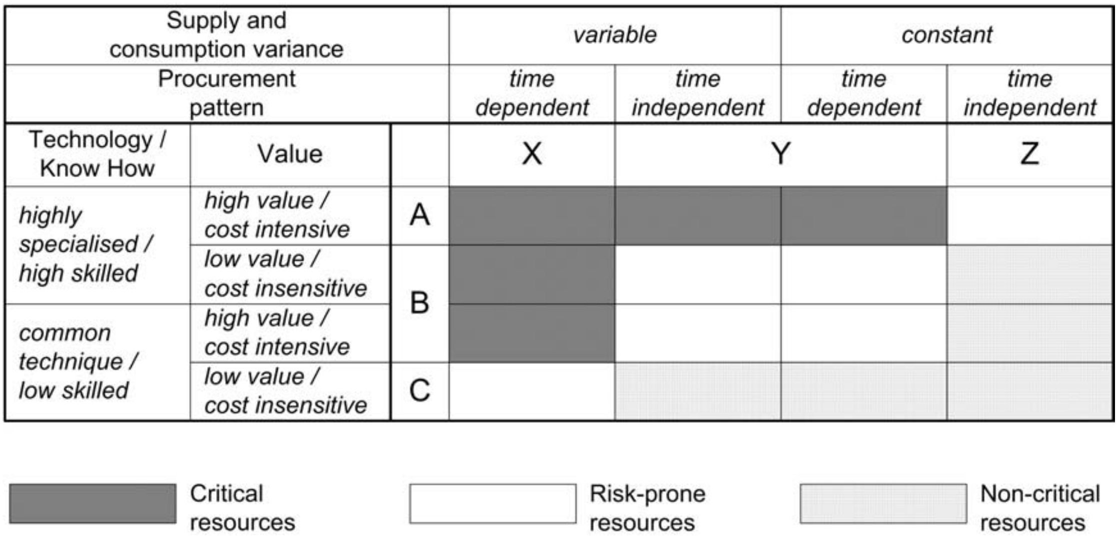


Figure 1: Classification of resources into critical, non-critical and risk-prone resources

While detailed project planning is recommended for critical resources, less effort shall be put into non-critical resources. For instance, low mass, low value construction material can be classified as materials of CZ-category. Its supply is a necessary condition to execute the project, but due to the low criticality of the resource it is not subject of a detailed resource allocation planning.

FUTURE PATH FOR THE APPLICATION OF RESOURCE-CONSTRAINED SCHEDULING IN CONSTRUCTION

Construction industry projects involve complex packages of work, for which design and contracting organizations are responsible; the product is generally large, discrete and prototypical (Abeyasinghe *et al*. 2001). The main particularities of the construction industry and construction industry projects are: design-to-order production; shifting production sites; spatial constraints; seasonal dependency; construction specific legislation, in particular environmental legislation; time/resource trade-offs; simultaneous multiple projects; and a combination of multiple objectives of time, cost, quality and resource levelling.

To demonstrate how quantitative project planning models can be successfully introduced to construction we introduce a generalized resource-constrained project scheduling model in the following. The formulation of this model is further customized to the context of construction projects. In particular, the customization focuses on the characteristics objective and complexity of projects as listed in Table 1.

A generalized resource-constrained project scheduling model

Approaches to project planning, scheduling and resource allocation in construction cover techniques based on the line of balance (LOB) concept (e.g. Tokdemir *et al.* 2006) for linear scheduling and repetitive construction operations, as well as heuristics and optimization models, such as the resource constrained scheduling problem.

The classical resource constrained project scheduling problem (RCPSP) describes a single project that consists of $j = 1,...,J$ activities, also known as jobs, operations or tasks, with a known constant duration of d_j periods. It is characterized by a deterministic finish-to-start precedence relation in an activity-on-node (AON) network, which means that an activity cannot be started before all its predecessors have been finished. Furthermore, pre-emption of the jobs is not allowed, i.e. whenever a job has been started at the beginning of period t it must be performed without interruption in the time periods $t,...,t + d_j - 1$. Additionally, resource constraints have to be observed during the procession of the jobs, whereas job j requires constant q_{jr} units of the renewable resource type $r \in R$ during every period of its duration. The resource type r is known and available in a constant amount Q_r over the whole planning horizon. Thus, jobs might not necessarily be scheduled at their earliest possible (precedence feasible) start time. The objective of the RCPSP is to find a non-pre-emptive schedule (i.e. a feasible schedule) by assigning starting times to the jobs such that the precedence and resource constraints are satisfied following one or more targets. An early mathematical programming formulation was given in Pritsker *et al.* (1969).

The most commonly considered objective of the RCPSP is the minimization of the project finishing time. This is mainly due to the following reasons (Kolisch 1996: 180):

1. The majority of income payments of projects occurs at the end of a project or at the end of predefined project phases. Finishing the project early reduces the amount of tied-up capital.
2. The quality of forecasts tends to deteriorate with the distance into the future of the period for which they are made. Minimizing the project duration reduces the planning horizon and, therefore, the uncertainty of data.
3. Finishing products as early as possible lowers the probability of time-overruns of the project.
4. By freeing resource capacity as early as possible, the flexibility of the company can be raised in order to better cope with changes of the economic environment.
5. Additionally, a high resource utilization at the beginning of the planning horizon leads to a larger amount of free resources at the end of the planning horizon and, thus, rises to ability to accept and process new projects.

With the assumptions made, the RCPSP can be modelled as mixed integer program (MIP) as introduced in the following:

$$\text{MIN} \quad \Phi = \sum_{t=EF_J}^{LF_J} t \cdot x_{Jt} \tag{1}$$

subject to

$$\sum_{t=EF_j}^{LF_j} x_{jt} = 1 \qquad j = 1,\dots,J \tag{2}$$

$$\sum_{t=EF_h}^{LF_h} t \cdot x_{ht} \le \sum_{t=EF_j}^{LF_j} (t - d_j) \cdot x_{jt} \qquad j = 1,\dots,J\,;\ h \in P_j \tag{3}$$

$$\sum_{j=1}^{J} \sum_{\tau=t}^{t+d_j-1} q_{jr} \cdot x_{j\tau} \le Q_r \qquad r \in R\,;\ t = 1,\dots,\overline{T} \tag{4}$$

$$x_{jt} \in \{0,1\} \qquad j = 1,\dots,J\,;\ t = 1,\dots,\overline{T} \tag{5}$$

The objective function (1) minimizes the project finishing time with $\overline{T}$ being the end of the planning horizon. Constraints (2) ensure that every job is processed once. Constraints (3) are precedence constraints of jobs with P_j denoting the set of immediate predecessors of job j. The duration of job j is represented by d_j. Constraints (4) limit the resource demand q_{jr} of the renewable resource $r \in R$ of jobs j, which are currently processed in order not to exceed the constant resource availability per period Q_r. Finally, constraints (5) define the decision variable $x_{jt} \in \{0,1\}$ as binary, with $x_{jt} = 1$ if job j ends in period t, 0 else.

Objectives of project scheduling

While the most commonly considered objective of the RCPSP is, as already pointed out, the minimization of the project finishing time, construction project management in general covers a much wider scope of objectives. The aggravating factor in construction project planning, which is closely related to the complexity of the project, is the type and the number of participants involved in a project who claim the fulfilment of their various interests (Schultmann and Sunke 2006). Objectives might hereby be induced either by the project owner, its stakeholders, such as subcontractors or material suppliers, but also be imposed by a regulatory framework or other external conditions. These objectives can address different issues such as time, cost and resource allocation etc. For a comprehensive overview of various objectives as an extension of the RCPSP, see Klein (1999) and Kolisch and Padman (2001).

Time objectives address the optimization of measures related to finishing times, make spans, tardiness of jobs and projects. Among these are the minimization of the make span of a project i and the minimization of the (weighted) flow time of activities j. A collection of time related objectives can be found, for example, in Schultmann (1998: 123–30) and Kolisch and Padman (2001: 250–1).

Monetary oriented project objectives comprise resource-cost oriented objectives, activity-cost oriented objectives and objectives concerning the net present value of a project (Kolisch and Padman 2001: 251). Resource-cost oriented objectives are reflected in two extensions of the RCPSP: time-constrained project scheduling problem (TCPSP) and resource investment problem (RIP). The objective of the TCPSP is the minimization of additional resource costs for additional resource consumption if the project finish is set. The RIP aims at determining a non-delay schedule and the amount of each resource provided minimizing total costs (e.g. Demeulemeester 1995; Möhring 1984). Considering activity-cost oriented objectives so called time/cost trade-off problems occur. The underlying assumption is that the activity duration might be influenced by the amount of money spent for processing (e.g. Demeulemeester *et al*. 1996; Vanhoucke 2005; Icmeli and Erenguc 1996). Additionally, bonuses and penalty costs for project finish, or both, negative as well as positive cash flows as reflected in the net present value (NPV) of a project can be considered. Problems aimed at maximizing the NPV depending on the time at which cash flows occur are called resource constrained project scheduling problem with discounted cash flows (RCPSP-DCF) (e.g. Chui and Tsai 2002) with various extensions, for instance, multiple-projects, multiple-processing modes (e.g. Ulusoy *et al*. 2001; Józefowska *et al*. 2002; Kim and Leachman 2003; Lawrence and Morton 1993; Mika *et al*. 2005).

While costs are the essential part in the TCPSP, the focus of *resource-oriented objectives* is not to allocate resources to activities minimizing costs or maximizing benefits but to allocate resources in a way such that deviations in resource consumption per period are minimized. This problem is considered as resource levelling problem (RLP) (e.g. Bandelloni *et al*. 1994; Hegazy 1999; Neumann and Zimmermann 2000).

While the first three categories of objectives have already been studied extensively in literature, environmental objectives have not yet been paid reasonable attention to in project scheduling considerations although widely discussed regarding environmental conscious behaviour related to sustainable development. In particular, these objectives can address the maximization of material to be recovered in deconstruction projects (e.g. construction materials such as wood, bricks, steel, modules, sanitary installation etc.) and the minimization of emissions (noise, pollution, etc.) during construction projects.

Complexity

The complexity of a project or a project planning problem is determined by numerous factors related to the micro and macro complexity of a project (see Table 1). Particularly concentrating on the complexity caused by different execution alternatives of a construction or deconstruction activity, as very common in practice, so called trade-offs between input of resources and the duration of that activity occur.

In the RCPSP, however, each job is processed in a single alternative, i.e. each job is assigned a deterministic resource consumption and a corresponding duration (e.g. Christofides *et al*. 1987; Davis and Patterson 1975). If a job can be processed in more than one way, these alternatives are described as modes. These modes are representations of time/resource trade-offs (in contrast to time/cost trade-offs as addressed). Time/resource trade-offs occur when the duration of a job is affected by the bundle of input resources and can therefore be decreased/increased at the expense of providing additional/less resources or by using different resources. “For example, an excavation may be dagged by five construction workers within a week, whereas the same work may be performed by an excavator within a single day.” (Klein 1999: 96). Resource/resource trade-offs are a special case of time/resource trade-offs and represent the substitution of resources needed to execute a job without affecting the duration of the job (Demeulemeester and Herroelen 2002: 500).

The relevancy of this problem is evident in deconstruction processes of buildings. As disposal costs for building waste or deconstructed material raises a separation of different types of material is a necessary condition to enable a reuse and recycling of building waste and material. The quality of the deconstructed material and its suitability for reuse and recycling can be influenced by the technical and organizational planning of the deconstruction process and, hence, the chosen processing option, respectively mode, of each job (Schultmann 2003: 335; Schultmann 2003: 56-7).

The modelling of the RCPSP using modes results in the multi-mode resource constrained project scheduling problem (MMRCPSP). In the MMRCPSP formulation each job *j* is assigned a mode *m* defining the relation between resource consumption q_{jmr} and job duration d_{jm} in one of several different modes $m = 1,..., M_j$. The primary objective of the MMRCPSP is, according to the RCPSP, to minimize the project finishing time by selecting an execution mode for each activity and assigning feasible finishing times of the jobs according to the resource and precedence constraints.

SOLUTION PROCEDURES AND APPLICATIONS

Solution procedures for the RCPSP and its extensions MMRCPSP and MMRCMPSP have attracted intensive research since the late 1950s. These solution procedures are divided into exact algorithms and heuristic approaches. Comprehensive reviews for the RCPSP and its solution procedures can be found in (Brucker et al. 1999; Demeulemeester and Herroelen 2002; Kolisch 1996; Kolisch and Padman 2001; Kolisch and Hartmann 2006).

Despite the theoretical evaluation some practical applications are given in literature to proof the appropriateness of proposed solution procedures for practical planning problems. In the construction industry, case studies were undertaken, for instance, by Tsubakitani and Deckro (1990) and Chiu and Tsai (2002). A successful application of the RCPSP with multiple modes was given by Schultmann and Rentz (2002), who applied the model to deconstruction projects.

CONCLUSIONS

Our investigations to project planning and scheduling models showed a high potential for these in construction planning. The RCPSP can be applied to a variety of different classes of construction projects. It serves not only as a framework for resource allocation in construction project planning, but it can also easily be adapted to different project structures and different project environments. This includes, for instance, repetitive, multi-mode or multiple projects as well. Therefore, no differentiation between problem classes is necessary, such as applying the LOB concept exclusively to projects of repetitive nature. Additionally, the RCPSP provides freedom to integrate external constraints (e.g. legislation, market regulations) and multiple objectives.

However, although the RCPSP and its extensions seems to be a universal solution approach for a variety of project planning problems in practice and in construction in particular, one should not abstract away from the fact that special cases, like repetitive projects might be better solved with customized methods, such as LOB with the exceptions, that external constraints and multiple objective function are not considered. Therefore it is necessary, to further evaluate and prove the appropriateness of the RCPSP for the various project planning problems in real world situations in construction.

In this paper we have assumed a deterministic project environment. Approaches to consider uncertainty, e.g. simulation or fuzzy scheduling, have not been addressed. The same holds true for the consideration of multiple objectives as well as for planning projects simultaneously. Moreover, we have to pay attention to the fact that even a nearly perfect planning, considering resource constraints, different environments, uncertainty, vague information etc. can not replace a proper project control. Taking this into account, the need for more “intelligent” approaches like reactive scheduling, opportunistic principles in planning and control becomes obvious.

ACKNOWLEDGEMENT

We would like to thank two anonymous referees for their helpful comments.

REFERENCES

Abeyasinghe, M C L, Greenwood, D J and Johansen, D E (2001) An efficient method for scheduling construction projects with resource constraints. *International Journal of Project Management*, **19**(1), 29–45.

Bandelloni, M, Tucci, M and Rinaldi, R (1994) Optimal resource leveling using non-serial dyanamic programming. *European Journal of Operational Research*, **78**(2), 162–77.

Brucker, P, Drexl, A, Möhring, R, Neumann, K and Pesch, E (1999) Resource-constrained project scheduling: notation, classification, models and methods. *European Journal of Operational Research*, **112**, 3–41.

Burns, S A, Liu, L and Feng, C-W (1996) The LP/IP hybrid method for construction time-cost trade-off analysis. *Construction Management and Economics*, **14**, 265–76.

Chiu, H N and Tsai, D M (2002) An efficient search procedure for the resource-constrained multi-project scheduling problem with discounted cash flows. *Construction Management and Economics*, **20**(1), 55–66.

Christofides, N, Alvarez-Valdéz, R and Tamarit, J M (1987) Project scheduling with resource constraints: A branch and bound approach. *European Journal of Operational Research*, **29**, 262–73.

Davis, E W and Patterson, J H (1975) A comparison of heuristic and optimum solutions in resource-constrained project scheduling. *Management Science*, **21**(8), 944–55.

Demeulemeester, E (1995) Minimizing resource availability costs in time-limited project networks. *Management Science*, **41**(10), 1590–8.

Demeulemeester, E and Herroelen, W (2002) *Project Scheduling – A Research Handbook*, International Series in Operations Research and Management Science, **49**. Boston, MA: Kluwer Academic Publishers.

Demeulemeester, E, Herroelen, W and Elmaghraby, S (1996) Optimal procedures for the discrete time/cost trade-off problem in project networks. *European Journal of Operational Research*, **88**(1), 50–68.

Elbeltagi, E, Hegazy, T, Hosny, A H and Eldosouky, A (2001) Schedule-dependent evolution of site layout planning. *Construction Management and Economics*, **19**(7), 689–97.

El-Rayes, K and Moselhi, O (1998) Resource-driven scheduling of repetitive activities. *Construction Management and Economics*, **16**(4), 433–46.

Hegazy, T (1999) Optimization of resource allocation and leveling using genetic algorithms. *Journal of Construction Engineering and Management*, **125**(3), 167–75.

Herroelen, W and Leus, R (2005) Identification and illumination of popular misconceptions about project scheduling and time buffering in a resource-constrained environment. *Journal of Operational Research Society*, **56**, 102–9.

Icmeli, O and Erenguc, S (1996) The resource constrained time/cost trade-off project scheduling problem with discounted cash flows. *Journal of Operations Management*, **14**(3), 255–75.

Józefowska, J, Mika, M, Waligóra, G and Weglarz, J (2002) Multi-mode resource-constrained project scheduling problem with discounted positive cash flows - simulated annealing vs. tabu search. *Foundations of computing and decision sciences*, **27**(2), 97–114.

Karshenas, S and Haber, D (1990) Economic optimization of construction project scheduling. *Construction Management and Economics*, **8**, 135–46.

Kim, S O and Leachman, R C (2003) Multi-project scheduling with explicit lateness costs. *IIE Transactions*, **25**(2), 34–44.

Klein, R (1999) *Scheduling of Resource-Constrained Projects.* Norwell, MA: Kluwer Academic Publishers.

Kolisch, R (1996) Efficient priority rules for the resource-constrained project scheduling problem. *Journal of Operations Management*, **14**, 179–92.

Kolisch, R and Hartmann, S (2006) Experimental investigation of heuristics for resource-constrained project scheduling: An update. *European Journal of Operational Research*, **174**(1), 23–37.

Kolisch, R and Padman, R (2001) An integrated survey of deterministic project scheduling. *Omega – The International Journal of Management Science*, **29**(3), 249–72.

Lawrence, S R and Morton, T E (1993) Resource-constrained multi-project scheduling with tardy costs: Comparing myopic, bottleneck, and resource pricing heuristics. *European Journal of Operational Research*, **64**(2), 168–87.

Mika, M, Waligóra, G and Weglarz, J (2005) Simulated annealing and tabu search for multi-mode resource-constrained project scheduling with positive discounted cash flows and different payment models. *European Journal of Operational Research*, **27**(2), 639–68.

Möhring, R H (1984) Minimizing costs of resource requirements in project networks subject to a fixed completion time. *Operations Research*, **32**, 89–120.

Moselhi, O and Lorterapong, P (1993) Near optimal solution for resource-constrained scheduling problems. *Construction Management and Economics*, **11**, 293–303.

Neumann, K and Zimmermann, J (2000) Procedures for resource leveling and net present value problems in project scheduling with general temporal and resource constraints. *European Journal of Operational Research*, **127**(2), 425–43.

Payne, J H (1995) Management of multiple simultaneous projects: a state-of-the-art review. *International Journal of Project Management*, **13**(3), 163-68.

Pritsker, A A B, Watters, L J and Wolfe, P M (1969) Multi-project Scheduling with Limited Resources: A Zero-One Programming Approach. *Management Science*, **16**, 93–108.

Schultmann, F (1998) *Kreislaufführung von Baustoffen - Stoffflußbasiertes Projektmanagement für die operative Demontage- und Recyclingplanung von Gebäuden*. Berlin: Erich Schmidt Verlag.

Schultmann, F (2003) Stoffstrombasiertes Produktionsmanagement – Betriebswirtschaftliche Planung und Steuerung industrieller Kreislaufwirtschaftssysteme. Berlin: Erich Schmidt Verlag.

Schultmann, F and Rentz, O (2002) Scheduling of deconstruction projects under resource constraints. *Construction Management and Economics*, **20**(5), 391–401.

Schultmann, F and Sunke, N (2006) Sustainable construction in a multi-project environment – The contribution of stakeholder's perspectives in life-cycle projects. *In*: *Proceedings of the 2nd CIB International Conference on Smart and Sustainable Built Environments 2006 (SASBE2006)*, 15 – 17 November 2006, Shanghai, China.

Shtub, A, Bard, J F and Globerson, S (1994) *Project Management – Engineering, Technology, and Implementation*. Englewood Cliffs: Prentice Hall.

Slack, N, Chambers, S, Harland, C, Harrison, A and Johnston, R (1998) *Operations Management*. London: Pitman Publishing.

Slowinski, R (1979) Multi-objective Network Scheduling with Efficient Use of Renewable and Non-Renewable Resources. *In*: *Proceedings of the 6th INTERNET Congress*, 455–66.

Spinner, M P (1997) *Project Management – Principles and Practices.* Englewood Cliffs: Prentice Hall.

Tokdemir, O B, Arditi, D and Balcik, C (2006) ALISS: Advanced Linear Scheduling System. *Construction Management and Economics*, **24**, 1253–67.

Tsai, D M and Chiu, H N (1996) Two heuristics for scheduling multiple projects with resource constraints. *Construction Management and Economics*, **14**(4), 325–40.

Tsubakitani, S and Deckro, R F (1990) A heuristic for multi-project scheduling with limited resources in the housing industry. *European Journal of Operational Research*, **49**(1), 80–91.

Ulusoy, G, Sivrikaya-Serifoglu, F and Sahin, S (2001) Four Payment Models for the Multi-Mode Resource Constrained Project Scheduling Problem with Discounted Cash Flows. *Annals of Operations Research*, **102**, 237–61.

Vanhoucke, M (2005) New computational results for the discrete time/cost trade-off problem with time-switch constraints. *European Journal of Operational Research*, **165**(2), 357–74.

Weglarz, J (1979) New Models and Procedures for Resource Allocation Problems. *In*: *Proceedings of the 6th INTERNET Congress*, 521–30.

APPLYING ANT COLONY SYSTEM TO SOLVE CONSTRUCTION TIME-COST TRADE-OFF PROBLEM

Yanshuai Zhang, S. Thomas Ng and Mohan M. Kumaraswamy

Department of Civil Engineering, The University of Hong Kong, Pokfulam, Hong Kong

Time-Cost Trade-off (TCT) is a very common problem in the construction domain. The concept of TCT is to minimize either the total cost or total duration of a project at a predetermined construction duration or amount respectively. Many techniques have already been proposed for solving the TCT problems, and examples of these include the heuristic methods, mathematical approaches and evolutionary-base optimization algorithms (EOAs). Among these techniques, the EOAs such as the genetic algorithms, ant colony optimization, particle swarm algorithms, etc. are considered more promising for TCT due to their ability to cope with the dynamic behaviour and their efficiency. The Ant Colony System (ACS), being an extension of the basic ant colony optimization algorithms, has good potential for solving network problems like TCT due to its excellent ability to identify the best path of a network. In this paper, an ACS model for discrete TCT problems is introduced. Having developed the model in Visual Basic and integrated with Microsoft Project, a series of computational experiments is conducted to compare the performance of the proposed ACS model with other previous developed methods. The performance and weakness of the ACS model for TCT problem is highlighted to conclude this paper.

Keywords: time-cost trade-off problem, project management, ant colony system.

INTRODUCTION

One of the most important roles of a construction planner is to allocate appropriate and adequate resources to a construction project to ensure it is completed on time and within budget. Selecting an appropriate equipment output and crew size as well as establishing the correct sequence and duration for activities in a construction project so as to meet the contract duration at the minimum cost is therefore the focus of a Time-Cost Trade-off (TCT) analysis.

Several techniques have been proposed for the TCT analysis, and these include the heuristic methods, mathematical approaches and Evolutionary-based Optimization Algorithms (EOAs). Heuristic methods are non-computer approaches that rely on the rules-of-thumb of decision-makers. Mathematical approaches convert the TCT problems into mathematical models and utilize the linear programming, integer programming or dynamic programming techniques to solve the problems. Both the heuristic and mathematical methods have their own limitations, of which, the most critical constraint is their inability to guarantee the generation of an optimal.

In this paper, an EOA known as the Ant Colony System (ACS) is proposed to solve the construction TCT problems. The paper proceeds by a brief introduction of the EOAs. This is followed by highlighting the key features of the ACS-based TCT model. A case project is used to illustrate the performance of the proposed model, and the paper is concluded by comparing the results of the ACS-based TCT model and those generated by other modelling approaches.

EVOLUTIONARY-BASED OPTIMIZATION ALGORITHMS

Striving to identify a global optimal solution, many researchers have been exploring the potentials and pitfalls of adopting EOAs for TCT problems. EOAs are stochastic search methods that mimic the metaphor of natural biological evolution and/or the social behaviour of natural species. According to Lovbjerg (2002), such behaviour is guided by learning, adaptation and evolution.

Apart from genetic algorithms (GAs) (Feng *et al*. 1997, 2000), other EOAs being inspired by the natural processes include the Ant Colony Optimization (ACO) (Dorigo *et al*. 1996), memetic algorithms (Moscato 1989), particle swarm optimization (Kennedy and Eberhart 1995) and shuffled frog leaping (Eusuff and Lansey 2003). The concepts of these methods and their application on construction TCT problems can be found in Elbeltagi *et al*. (2005).

While all these EOA techniques discussed above can be used for solving discrete TCT problems, the results of Elbeltagi's study show ACO outperformed the others in terms of both the solution quality and its process time. Acknowledging the strength of ACO, it is interesting to find out whether another member of the ant algorithms family – the Ant Colony System (ACS) can further improve the quality of this type of decisions.

ANT COLONY SYSTEM

ACO was first proposed by Colorni *et al*. (1991) as a meta-heuristic scheme to locate near-optimal solutions. By simulating the behaviours of real ants moving along a weighted connected graph, it is able to solve many complex combinatorial optimization problems such as the Travelling Salesman Problem (TSP) through the ACO (Dorigo *et al*. 1996; Stützle and Dorigo 1999).

As reported by Dorigo and Stützle (2004: 68), the Ant System (AS) (Dorigo *et al*. 1992) which is the most primitive ACO algorithm was introduced for solving the TSP problem. Then, a count of extensions of AS were inspired to improve its performance such as ACS, the elitist ant system, the max-min ant system, etc. Different updating rules of the pheromone are indeed the main difference between the AS and its extensions (Dorigo and Stützle 2004: 68–9). Hence, the most important area in which the ACS outperforms the AS lies with the pheromone updating rule.

There are two components for updating its pheromone in ACS namely the local updating and global updating respectively. The experiment was conducted by the authors, and the results show that ACS outperforms the basic AS not only on the solution quality but also on the processing time. As a result, it is more likely to generate the near-global solutions much quicker while a premature convergence can also be avoided. Therefore, the ACS together with other ACO algorithms should have great potential for solving optimization problems like scheduling and flowshop problems.

ACS-BASED TCT MODEL

The discrete TCT problem can be represented by a weighted graph based on the ACS approach such that the activities as well as various construction methods for each activity constitute the networks. The objective function would be the total cost of a project which means the sum of direct cost and indirect cost as determined by:

$$f = \sum_{i=1}^{L} C_i + D \cdot ic \tag{1}$$

where f is the objective function; C_i is the direct cost of i^{th} activity; D is the project duration; and ic is the indirect cost which is a determined value.

Suppose there are L_i options for activity i, and an ant in activity i selects option k using the rule adapted from the ACS-TSP model originated by Gambardella and Dorigo (1996) as follows:

$$P_{ik} = \frac{\tau_{ik}}{\sum_{k=1}^{Li} \tau_{ik}} \tag{2}$$

where P_{ik} is the probability that k^{th} option of activity i being chosen; and τ_{ik} is the pheromone of k^{th} method option of activity i in the TCT problem.

As discussed, the pheromone updating rules of ACS model include two steps as illustrated bellow. The first step is comparable to the basic ACO approach as developed by Elbeltagi *et al*. (2005) for TCT modelling:

$$\tau_{ik} = \rho\tau_{ik} + \Delta\tau_{ik} \tag{3}$$

$$\Delta\tau_{ik} = (1-\rho)\tau_0 \tag{4}$$

where τ_{ik} is the concentration of pheromone; ρ is the pheromone evaporation rate (from 0 to 1); and τ_0 is a small constant.

The second step which makes ACS different from basic ACO is the global updating rule which is performed after an entire iteration is completed. The pheromone concentration will be updated in the options belonging to the best ant in this iteration according to the following equation:

$$\tau_{ik} = (1-\alpha)\tau_{ik} + \alpha \cdot R \cdot f_{iter\text{-}bestant} \tag{5}$$

where α is the evaporation rate in global-updating process; R is a constant referred as the pheromone reward factor; and $f_{iter\text{-}bestant}$ is the fitness value of the best ant in this iteration.

MODEL DEVELOPMENT

Based on the above concepts, an ACS-based TCT model is developed in four phases: (i) initializing the parameters including the number of ants and τ_0; (ii) for each ant, deriving a solution by travelling from the first activity to the last activity of the project according to the selection probability function as shown in Equation 2; (iii) for each trail, updating the pheromone locally and globally according to Equations 3 and 5 respectively; and (iv) checking the termination criteria which is the maximum number of iterations. Should the criteria be satisfied, the best solutions will be shown as output. Otherwise, the algorithm would be repeated. With that, a model was developed using Microsoft Visual Basic and the model is linked to Microsoft Project. Figure 1 shows the process involved in the proposed program.

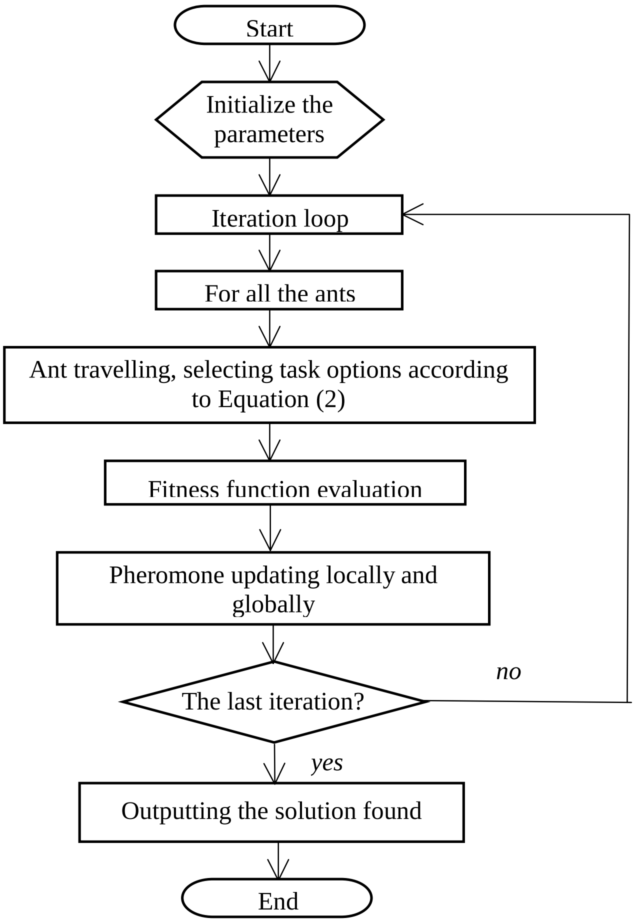


Figure 1: Flowchart for ACS-based TCT model

For comparison, the same case project employed in Elbeltagi's study (Table 1) was fed into the developed ACS-based TCT model. As shown in Table 1, the activities, their predecessors as well as their best guess duration and cost are presented. Besides, there are also five alternative methods of construction that vary from cheap but slow (option 5) to fast yet expensive (option 1). D1 to D5 represent the duration of those alternatives, while the costs of those options are highlighted by C1 to C5. After extensive experimentation, 10 ants and 50 iterations were found suitable for this case. The other parameters can be set as: $\rho=\alpha=0.9$, $\tau_0=0.1$, $R=50$.

Table 1: Details of case project (Elbeltagi *et al*. 2005)

Activity	Depends on	Option1		Option2		Option3		Option4		Option5	
		D1	*C1*	*D2*	*C2*	*D3*	*C3*	*D4*	*C4*	*D5*	*C5*
1	-	14	2,400	15	2,150	16	1,900	21	1,500	24	1,200
2	-	15	3,000	18	2,400	20	1,800	23	1,500	25	1,000
3	-	15	4,500	22	4,000	33	3,200				
4	-	12	45,000	16	35,000	20	30,000				
5	1	22	20,000	24	17,500	28	15,000	30	10,000		
6	1	14	40,000	18	32,000	24	18,000				
7	5	9	30,000	15	24,000	18	22,000				
8	6	14	220	15	215	16	200	21	208	24	120
9	6	15	300	18	240	20	180	23	150	25	100
10	2,6	15	450	22	400	33	320				
11	7,8	12	450	16	450	20	300				
12	5,9,10	22	2,000	24	1,750	28	1,500	30	1,000		
13	3	14	4,000	18	3,200	24	1,800				
14	4,10	9	3,000	15	2,400	18	2,200				
15	12	12	4,500	16	3,500						
16	13,14	20	3,000	22	2,000	24	1,750	28	1,500	30	1,000
17	11,14,15	14	4,000	18	3,200	24	1,800				
18	16,17	9	3,000	15	2,400	18	2,200				

In this project, if a planner or manager selects the last option for all the activities, a network as shown in Figure 2 can be produced, with duration = 169 days and total cost = \$184,240 (indirect cost = \$500/day).

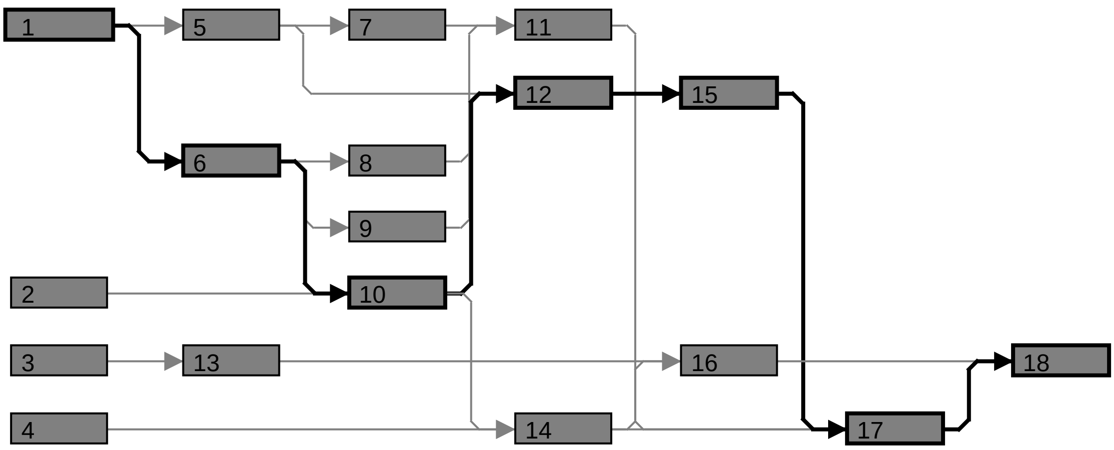


Figure 2: Activity-on-node diagram for the project with activities on critical path in bold

RESULTS AND COMPARISON

The indirect cost adopted in this case project is \$500/day. With the initial schedule exceeding a desired deadline of 110 days, it is necessary to search for an optimum set of options that meet the deadline at the minimum total cost. Figure 3 shows the convergence of this ACS-based TCT model in solving the above case project. It is noted that the total cost is very high at the beginning (\$186,820) but converges to its optimal value after a dozen of iterations. Even when 50 iterations was adopted in this case, the best result was achieved at the 41st iteration with a total cost of \$161,270 and a total duration of 110 days, which is in turn the desired deadline of this case project.

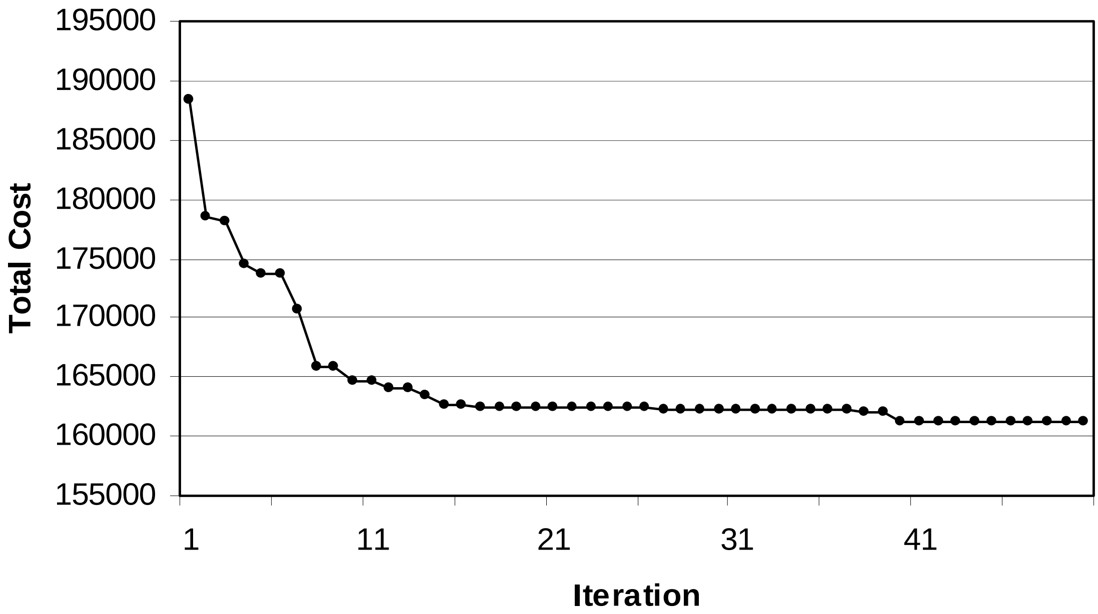


Figure 3: Convergence of project total cost

The results obtained from the ACS-based TCT model are compared with those generated by other EOAs found in previous studies (Elbeltagi *et al*. 2005). As shown in Table 2, the optimal solution of 110 days at a cost of $161,270 being generated by the current model is the same as that derived by the memetic algorithm and ACO models. However, the results generated by the GAs and shuffled flog lapping approaches are inferior to the proposed model. In the case of the GA model, the minimum duration was 113 days at a cost of $162,270 with a difference of three days and $1,000 for the duration and cost respectively.

Table 2: Results of EOAs in TCT problem

Algorithm	Minimum duration (days)	Minimum cost ($)	Processing time (s)
GAs	113	162,270	16
SFL	112	162,020	15
MAs	110	161,270	21
ACO	110	161,270	10
ACS	110	161,270	N/A

Without executing various models in the same computer, it is impossible to compare the time taken by ACS-based TCT model with that of other algorithms. Yet, as ACS is an extension of the basic ACO approach, it is sensible to compare the performance of these two algorithms. As shown in Table 3, the number of ants and number of iterations in the ACS-based TCT model are about 60% less than the ACO model respectively. Using the basic ACO model required 100 iterations to generate an optimal solution while only 41 iterations were taken by the ACS model. Hence, one can reasonably assume that the processing time of the current ACS model is much less than the basic ACO model and other EOA approaches (*cf:* Elbeltagi *et al*. 2005).

Table 3: Comparison between ACO-based model and ACS-TCT model

Description	ACO model	ACS model
Number of ants	30	10
Number of iterations to get the best solution	100	41

Stützle, T and Dorigo, M (1999) ACO algorithms for the travelling salesman problem. *In:* K Miettinen, M Makela, P Neittaanmaki and J Periaux (Eds.) *Evolutionary Algorithms in Engineering and Computer Science*. New York: Wiley.

DYNAMIC THREE-DIMENSION VISUAL SIMULATION FOR DAM CONCRETE CONSTRUCTION PROCESS

Lihua Chen,[1] Mingliang Shen, Yajie Dong and Yadong Mei

State Key Laboratory of Water Resource and Hydropower Engineering Science, Wuhan University, Wuhan, 430072, China

The construction of a concrete dam is an extremely complicated system project with lots of influencing factors. The model of construction simulation by using queuing theory is established. The construction system is considered as an exceptive queuing serving system. It accords with the practice construction process to apply time-event driven method to drive change of state in system. This not only remedies the influence of simulation precision that time step brings, but also effectively deals with the relationship between master clock and secondary clock. According to the requirement of visual simulation in waterpower projects, we make a data model by using discrete contour line database TIN, establishing DTM by transforming random lattice to formula grid, organizing time and spatial data of construction blocks, so that a 3D digital model of the dam which corresponds with the spatial–temporal relationship is formed. The dynamic visual system of the concrete dam construction process was developed by the authors. Based on the characteristics of the XiangJiaBa project which lies in southeast China, we apply the construction machine model of construction with several kinds of device set. Based on GIS, we express the complex spatial–temporal relationship between all aspects of the project schedule, and provide the basis data of visual decision making for scheme optimization, construction machinery matching, optimizing the execution programme of work.

Keywords: concrete, construction management, dam, simulation, virtual reality.

INTRODUCTION

The construction of a concrete dam is an extremely complicated system project which involves lots of influencing factors: the quantity is huge, the construction period is long, dam blocks are large quantities, placement machines are of different types, the structure of the dam and construction techniques are complicated, and the construction intensity is high; so, the construction design of a concrete dam is a complex and flexible task (Yuan 1996; Zhou 1998). Based on GIS, the dynamic three-dimensional visual simulation could be realized by the simulation achievement data and information, and express the complex spatial–temporal relationship between all aspects of the project schedule (Zhong *et al*. 2004). This method provides visualizing analysis data for optimizing the construction procedure, exploring construction machinery matching and accelerated construction and verifying dam construction period, and greatly improves the construction design and construction organization.

[1] zgfjclh@163.com

THE DESIGN IDEA AND CONFIGURATION OF SYSTEM

The system simulation model is classified into two types, named continuous system model and discrete system model according to their characteristics (Sun 1997). A discrete system is an event-driven dynamic system in which states change in the form of jumping. System transfer happens by a trail of discrete events. In the study of construction process simulation, the state properties of entities such as the construction state and construction information of each block and construction machine, change with events which influence the system at random times. Those variables changing with time are discrete and jumping, so the model of a concrete dam construction system is regarded as a discrete system.

The concrete dam construction simulation system consists of the following components: original database, computerized selection of blocks to be concreted, 2D and 3D image simulating and so on, which are independent and united by the main interface.

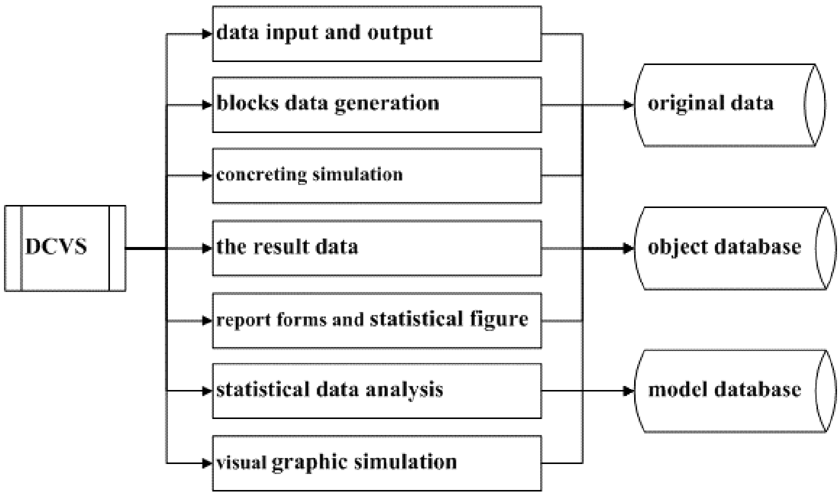


Figure 1**:** Schematic diagram of configuration in dynamic simulation system

THE KEY TECHNIQUES

Simulation comprehensive model

By using the simulated model of queuing theory, the construction system is considered as a special queuing serving system, which all kinds of construction mechanisms serve to the construction (Ioannou 1999). The queuing rules of construction are not according to first-come-first-served rule, after-come-first-served rule and priority rule, they are in accordance with the hierarchy of construction and the construct requirement of the height to queue. The construction serves of machine also does not instantly serve based on the queuing, it chooses the serving object on the consideration of the meeting of the constraints and the combination of first-construct of upstream dam (Trinh and Sharif 1996). The combination of time and event is used to drive the change of system state, which not only remedies the influence of simulation precision that time step brings, but also effectively deals with the relationship between master clock and secondary clock. A comprehensive model mostly faces with the transporting system and construction blocks, and provides time and spatial data for image simulation. The proceedings are shown as follows:

1. Simulation parameter input: initial machinery matching program, technical parameters and operating parameters of each construction machine, 3D

model, efficient working day, construction parameter (intervals between two layers, the time of removal model, height limitation of adjacent dam blocks, concrete initial setting time, the time of shore set, limitation in height caused by failing to dismantle, start time and end time of simulation and so on).

2. The data generation of blocks: The data generation has mostly relations with dam structure and the arrangement of concrete blocking and joint division. Concrete blocking is determined by the most width of the bottom of the dam, and the area and thickness of concrete pieces is determined by construction capability of the machine. By considering the spatial position and geometry dimension of the bottom outlets, the middle outlets, the top outlets, water diversion tunnel, ship lift dam section, generating diversion tunnel, sand escape, the top of weir on outlet dam section, the quantity and the spatial data of the block are calculated.

3. Construction simulation: First, we divide time limit for a project to day, to judge whether the day could work. Second, we divide a day to three teams (two team at high temperature season), and regard a team as a step. Third, each machine is scanned, if there is available block, drive the state of system by time and event driven method and transfer corresponding sub-model of construction machine serving (Wang *et al*. 2004).

4. The time and spatial data organization and visual simulation: the property of time of start and end of blocks incarnate the time characters, and show the dynamic process of concrete construction. The geometry property of blocks waiting to be concreted and the information of the blocks which have been concreted make up the whole data of time and space. The organization of time and spatial data is the basis of the 3D digital model which is used to carry out dynamic 3D visualizing by the function of GIS. Figure 2 shows the main process of simulation of comprehensive model.

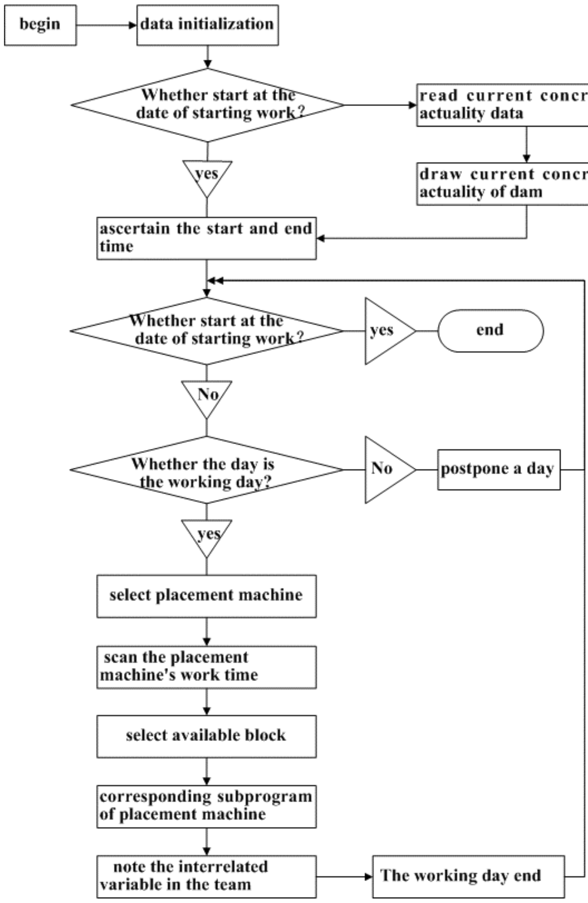


Figure 2: Comprehensive model flow chart

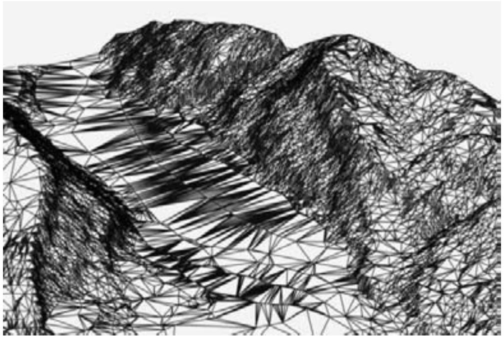
Machine service model

Aimed at the characteristics of different machines, continuous construction machines such as the tower-machine and belt conveyer, because of the symmetrical and continuous material, the running of the machine set is relatively easy in the construction process. Use dominant entity scan method and take the change of information and state of construction blocks as event influencing system. Discrete machines such as cable crane, gantry and tower cranes, belt conveyers, judge the available blocks by using dominant entity scan method and deal with the loading, loaded running, unloaded running, unloading and concreting process by time and event driven method.

Digital terrain model

DTM is used to express the digital model of 3D space with state of continuous gurgitation. There are many kinds of DTM, such as DEM, TIN, RNM and ECM.

Combining the characteristics of waterpower project construction systems, there are quite precise ground measures of data at former reconnaissance; making full use of the contour vector data in design data can reduce the cost of DEM data. This paper introduces a feasible method, that is, contour vector data are dealt with by eliminating evection, elevation insertion and generating the feature elevation point, data modelling makes by using discrete contour line database TIN, and random lattice transforms to formula grid, which establishes high precise DEM economically, quickly and reliably. When generating TIN, it can adequately think over the specialty of contour, and neatly adapts to any intricate image data, considers initial terrain, and can well present the intricate ground at the dam site. The DEM data have the advantage in precision and efficiency.



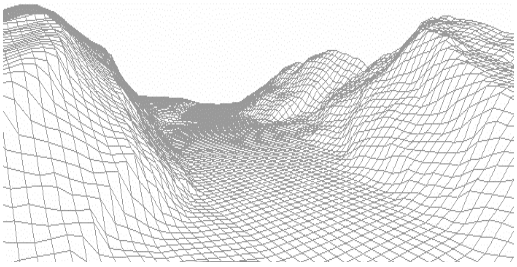


Figure 3: Triangulated irregular network **Figure 4:** Regular grid

Dam digital modelling

Spatial modelling of dam (Zhou 2003; Zhong 2003): the organization of spatial data relates to dam structure, the arrangement of concrete blocking and joint division and the requirement of temperature control. After ascertaining the geometry dimension data and space position data of thickness of construction, the bottom diversion outlets, the middle outlets, the top outlets, water diversion tunnel, ship lift dam, generating diversion tunnel, sand escape and the top of weir on outlet dam, by inserting calculation of control line of dam, it can get the information of number of dam blocks, thickness of construction, geometry dimension data of blocks, area and quantity of construction.

Spatial-temporal model of construction blocks: The geometry property of blocks waiting to be concreted is obtained by inserting calculation and the information of the blocks which have been concreted make the spatial-temporal model of blocks. The property of time of start and end of blocks incarnate the time character, and show the dynamic process of concrete construction. The organization of time and space data is the basis of 3D digital model which is used to carry out dynamic 3D visualizing by the function of GIS. This paper takes spatial-temporal model of bottom diversion outlets for example, as illustrated in Figure 5.

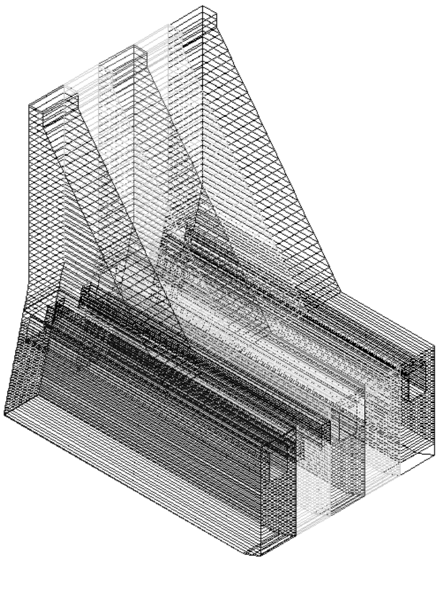


Figure 5: Spatial model of bottom diversion outlets

CASE STUDY

The XiangJiaBa project located in the county of Yibin in Sichuan province of China and in the county of Shuifu in Yunnan province of China, has the main function of generating electricity, and can anti-regulate upriver cascade hydropower stations. When completed, it can improve navigation, irrigation and sediment trapping conditions. According to the summary of conference checkup and opinion of experts, the two schemes (one scheme is three translation cable machine of 30t and three tower-machines (3+3), the other is three translation cable machine of 30t and two tower-machines) are both feasible. The former adds a tower-machine. The cost increases though it ensures the construction schedule, shortens the construction period, and brings the most economic interests causing by the first power generation in advance. Whereas the Three Gorges Project can provide three to four tower-machines for the XiangJiaBa project and avoiding wasting of resources, this paper makes a supplemental study on the ‘3+3’, and researches the disposal of cable machine, tower-machine and material supply line, purpose in Phases I and II, concretely working position, construction quantity, the scheme of joint division. It also studies the possibility of using pendulum-type cable crane in the XiangJiaBa project, by simulating different layout of pendulum-type cable crane of the scheme of two pendulum-type cable cranes, two translation cable machines and three tower-machines (2+2+3), on the ground of the present data and construction experience. Construction schedule, construction limit time, construction intensity and utilization ratio of pendulum-type cable cranes are compared. At this phase, simulating the schemes, the main parameters of various schemes are as listed in Table 1.

Table 1: The main parameters of various schemes

Scheme		**3□3**			**2□2□3I**			**2□2□3II**	
		none	one	two	none	one	two	none	one
Cable crane	Imax	39234	38575	39525	42347	44528	40043	41185	40218
	Iave	20835	19724	19559	23039	23143	23234	23982	22667
	Rave	43.12	39.24	37.34	47.42	45.29	44.06	48.66	44.57
	Rcom	56.38	54.52	51.88	62.00	62.92	61.21	63.63	61.93
Pendulum type cable crane	Imax	□	□	□	17467	15565	21621	19319	15675
	Iave	□	□	□	11726	9353	10704	12267	9494
	Rave	□	□	□	37.01	29.84	32.83	39.23	30.28
	Rcom	□	□	□	55.99	44.56	49.60	59.24	45.20
Tower machine	Imax	64444	65427	59040	59684	63799	62333	58075	62413
	Iave	43756	41681	41378	41823	40555	37388	42125	40732
	Rave	51.66	50.56	49.55	49.60	47.04	46.69	49.92	49.73
JGQ		□	57424	117597	□	57424	117597	□	117597
AImax		29.84	30.84	30.56	29.59	32.52	32.52	30.82	31.85
AIave		12.57	12.38	12.16	12.37	12.38	11.62	12.01	12.19
UI		2.37	2.49	2.51	2.39	2.63	2.80	2.57	2.61
TTL		64	65	66	65	65	69	67	66

Where Imax is the maximum intensity(10^4m^3/mon); Iave is the average intensity(10^4m^3/mon); Rave is the average utilization ratio (%); Rcom is the comprehensive utilization ratio (%); JGQ is the joint grouting quantity; AImax is all the maximum intensity of dam(10^4m^3/mon); AIave is the average intensity of dam(10^4m^3/mon); UI is the unbalanced index; TTL is the total time limit (month); none, one, two are the amount of the joint.

Compared with the '3+3' and '2+2+3I', '2 2 3II' is comparatively advanced in schedule, utilization ratio, construction intensity, construction limit time. The '3+3' and '2+2+3I' have advantages and disadvantages in the construction of concrete without a longitudinal joint and with one. The device set of the two schemes are feasible.

By combining simulation achievement with digital terrain model and data modelling of dam, it distinctly expresses the complex spatial–temporal relationship between all aspects of the project schedule. Phase I starts in September of the second year; stops construction when construction reaches 280.0m in December of the third year, as the diversion discharge of Phase II. Figure 6 shows the appearance. The dam is concreted above to 340m in June of the seventh year, and is able to keep off the 1% frequency flood, then, scour outlet dam section starts to be concreted, all of dam sections are concreted in the corresponding period; Figure 7 shows the appearance.

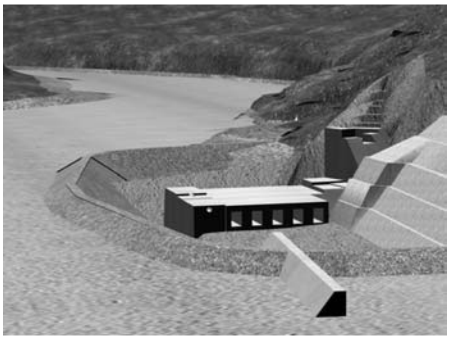


Figure 6: Construction appearance in December of the third year

Figure 7: construction appearance in June of the seventh year

CONCLUSIONS

The main influencing factors and the relationship of each other of the concrete construction is systemically analysed, the mechanism serve model and the construction simulated model are established, the dynamic emulation system of dam construction is explored. This system is used in the XiangJiaBa project, the technical and economical index such as construction schedule and construction image has been obtained. Based on the DEM and dam dimensional model, the dynamic three-dimension visual simulation with the harvest data is achieved by the using of the three-dimension technique, which distinctly expresses the complex spatial–temporal relationship between all aspects of the project schedule and provides a strong sustaining visual analysis data for construction design and management.

REFERENCES

Al-Jibouri, S, Mawdesley, M, Scott, D and Gribble, S J (2005) The application of a simulation model and its effectiveness in teaching construction planning and control. *In*: *ASCE International Conference on Computing in Civil Engineering*, 12–15 July 2005, 73–82.

Ioannou, P G (1999) Construction of a dam embankment with nonstationary queues. *In*: *Winter Simulation Conference Proceedings (WSC)*, 5–8 December 1999, Vol. 2, 921–8.

Sun, X (1997) *Computer simulation and program design in waterpower project*. Beijing: Chinese Water Resources and Hydropower.

Trinh, T T P and Sharif, N (1996) Assessing construction technology by integrating constructed product and construction process complexities: a case study of embankment dams in Thailand. *Construction Management and Economics*, **14**, 467–84.

Wang, R C, Shi, Y and Li, M C (2004) Study on the simulation of arch dam construction in Xiaowan project. *Sichuan Daxue Xuebao (Gongcheng Kexue Ban)/Journal of Sichuan University (Engineering Science Edition)*, **36**, 10–14.

Yuan, G (1996) *Construction of hydraulic project*. Beijing: Chinese Water Resources and Hydropower.

Zhong, D, Li, J, Zhu, H and Song, L (2004) Geographic information system-based visual simulation methodology and its application in concrete dam construction processes. *Journal of Construction Engineering and Management*, **130**, 742–50.

Zhong, D, Zhou, R and Liu, D (2003) Three-dimensional modeling and simulation of hydroelectric construction system. *Computer Simulation*, **20**(2), 86–91.

Zhou, K (1998) *Construction design and management in waterpower project.* Beijing: Chinese Water Resources and Hydropower.

Zhou, Ki, Mao, J and Shen, M (2003) Application of visual technology to concrete construction simulation in Longtan Project. *Engineering Journal of Wuhan University*, **5**, 47–50.

PROGRESS MONITORING OF ERECTION OF OFF-SITE PRODUCED UNITS USING PATTERN RECOGNITION

Ashraf Elazouni[1] and Osama Abdel-Wahhab[2]

[1]*King Fahd University of Petroleum & Minerals, Construction Engineering and Management Dept, PO Box 346, Dhahran 31261, Saudi Arabia*
[2]*University of Hail, Electrical Engineering Dept, PO Box 2440, Hail, Saudi Arabia*

Owing to numerous inevitable factors, the number of off-site produced (OSP) units of concrete structures being erected a day is generally not fixed but varies appreciably. Therefore, evaluating the completed work at a certain cut-off date by benchmarking against multiple possible outcomes becomes more meaningful than only one outcome. Pattern recognition (PR) techniques lend themselves well to accommodate evaluations based on multiple possible outcomes. The objective is to utilize PR to classify the work accomplishments achieved at predetermined cut-off dates. During the planning stage, a number of patterns are prepared at the cut-off dates and used to train the neural network (NN). During the construction stage, a pattern is prepared to describe the work accomplishment at a given cut-off date and entered to the trained NN. The NN will designate a date for the input pattern. Comparing the designated date to the actual cut-off date of the input pattern will indicate status of progress. The results were such that the developed NN could recognize patterns with an error rate of only 3.6%. Finally, the study proved that the concept and technique of PR offers a very effective and robust approach to monitor and evaluate the progress of construction projects.

Keywords: artificial intelligence, control, monitoring, off-site production, pattern recognition.

INTRODUCTION

Off-site production of concrete structures is a major accomplishment achieved during recent years which offers numerous benefits to the industry. Yet, the use by the construction industry of off-site production is limited. Blismas *et al*. (2006) argued that evaluating to what extent a building system should be produced off-site is inadequate within the industry. Blismas *et al*. advocated that the current evaluation methods for off-site production are cost- and not value-based, and therefore cannot account for the recognized benefits of off-site production. The consequence of this discrepancy is that off-site production invariably appears as an expensive alternative to the traditional on-site option. Blismas *et al.* concluded that the increasing complexity and value associated with off-site production mandates a more robust, transparent and inclusive evaluation methodology.

Beside the expeditious completion of construction, off-site production offers the merits of integrating design and manufacturing, thereby constructability issues can be properly

[1] elazouni@kfupm.edu.sa

addressed. In addition, the off-site production of the structural elements in an industrialized environment allows the achievement of high quality standards and expeditious production rates. The structural elements are produced in the manufacturing plant and transported to the job site, erected and serviced. Apart from production, other aspects of high relevance include the storage of the OSP units, the erection sequence and rate, and the definition of the construction path. Proper consideration should be given to each of these aspects so that the whole process will be smooth and efficient. However, the erection process of the OSP units represents the most critical activity that determines the total project duration. Thus, an effective progress monitoring and control system must be implemented during the erection process to ensure an expeditious project completion.

Owing to numerous factors, the number of OSP units being erected a day is generally not fixed but varies appreciably. These factors include the weather conditions, labour skill, manufacturing flaws, delivery rate, and the lifting-equipment capacity and conditions. These factors are out of control of the project manager and accordingly it becomes inevitable to accept their effect on the erection progress rate. Therefore, evaluating the number of the actually erected OSP units at a certain cut-off date by benchmarking against multiple possible outcomes becomes more meaningful and realistic than only one outcome. The pattern recognition concept lends itself well to accommodate evaluations based on multiple outcomes. The objective of this research is to utilize the pattern recognition concept and techniques to classify the work accomplishments achieved at regular predetermined cut-off dates. This classification will be used during the construction phase as a basis for monitoring and evaluating the progress of the erection process.

PREVIOUS RESEARCH

Several studies were reported in the literature related to computer-aided techniques that could be used for viewing site conditions and progress monitoring of construction projects. Hiroshi and Nobuoh (1993) described a filing system of construction pictures and its integration with a database. Abeid *et al*. (2003) described the development and implementation of an automated real-time monitoring system for construction projects programmed in a Delphi Environment. Riley and Whitesides (1999) conducted a study that assessed the feasibility, potentialities and best application for the implementation of digital image photography in the building design and construction process. Kubicki *et al*. (2004) focused on the use of building construction digital imagery as a computer-aided communication tool for improving coordination between the different actors involved in progress monitoring. Abd Majid *et al*. (2004) discussed the development of a conceptual integrated model that acts as a tool to monitor and evaluate the physical progress of a construction project at periodic intervals. The model integrates the 2D digital images captured from small-detail concrete structural elements at construction sites, the as-built AutoCAD drawings of these elements, and the standard scheduling tools such as Microsoft Project. Memon *et al.* (2005) discussed a digitalizing construction monitoring (DCM) model which integrates 3D CAD drawings and digital images to document as-built construction schedules.

Other studies were recently reported in the literature relating to techniques that could be used for progress monitoring and evaluating performance of construction projects.

Barraza *et al.* (2000) used a stochastic S-curve as an alternative to using the deterministic S-curve technique. Stochastic S-curves provide probability distributions for expected cost and duration for a given percentage of work completed. Monitoring project performance is performed by comparing the most likely budget and duration values, obtained from respective probability distributions for actual progress, with the project's actual data and cumulative cost. Cheng and Chen (2002) reported a study that focuses on developing an automated schedule monitoring system for precast building construction. The system, which is called ArcSched, is composed of a geographic information system (GIS) integrated with a database management system. Through systematic monitoring of the construction process and representation of the erection progress in graphics and colours, the scheduled components for erection are repetitively tracked. Construction progress is monitored through identifying the differences between the planned schedule and the real-time schedule. Nassar *et al.* (2005) presented a statistical approach, namely Weibull analysis, that can be used in conjunction with the earned value method to evaluate stochastically the schedule performance of construction projects. Poku and Arditi (2006) developed a system called PMS-GIS (progress monitoring system with geographical information system) to represent construction progress not only in terms of a CPM schedule but also in terms of a graphical representation of the construction that is synchronized with the work schedule.

It became obvious by surveying the previous research that utilizing pattern recognition concept and techniques in monitoring and evaluating the progress of construction projects, which is introduced in this study, is a novel approach in project management.

METHODOLOGY

During the planning phase of the project, cut-off dates separating periods at which the project will be regularly monitored during construction are specified. A monitoring period, typically a week, is determined when there is a need to describe a new stage of the project marked by the addition of an appreciable amount of work relative to the previous monitoring period. A special scheme is designed and used to indicate work accomplishments of the particular project. A scheme is basically a matrix with appropriate numbers of rows and columns which can be used conveniently to present the physical components of the building. The project work accomplishments at any time can be represented by filling in the appropriate cells of the schemes with 0–1 entries. As time goes on, the number of cells with entries of ones increases to reflect the extra work that was accomplished. During the planning stage of the project, a number of patterns are prepared for each cut-off date by filling in the cells of the schemes with 0–1 entries. The variation between the generated patterns at a given cut-off date is basically due to the variation of the daily number of erected OSP units. This set of schemes represents random patterns for the actual accomplishment at the project cut-off dates. The random patterns at all the cut-off dates along with the corresponding weeks will constitute the patterns to feed to the NN pattern recognition model. Some of the generated patterns will be used for training the NN and the remaining patterns will be kept for testing the trained NN.

After the construction stage of the project commences, the project monitoring is pursued regularly at the cut-off dates specified during the planning stage. A pattern is prepared to describe the work accomplishments at the desired cut-off date. This involves the measurement of work accomplishments already put in place up to the cut-off date. This pattern which represents the status of the project at the cut-off date is introduced as an input pattern to the trained NN model. The trained NN model will declare the week that the input pattern tends to converge to its patterns. Comparing the date of the declared week to the cut-off date of the input pattern will indicate the status of progress. Thus, the pattern recognition technique automatically implements the task of project monitoring and evaluation. A detailed implementation of the outlined methodology is demonstrated in the application section below.

APPLICATION

The study selected a real construction project as a test-bed to demonstrate the applicability of the pattern recognition technique. The test-bed project is a student housing project located in the campus of King Fahd University of Petroleum & Minerals (KFUPM) in Dhahran, Saudi Arabia. The facility constitutes nine identical L-shaped residential buildings, two common rooms and a Mosque. The superstructure of the buildings is constructed entirely using OSP concrete structural elements which are produced in a production plant and transported to the job site, erected and serviced. The OSP structural elements include load-bearing external and internal wall panels, parapets, beams, stair flights, solid slabs, hollow-core slabs and canopy. The external wall panel is 20cm thick, the internal wall panel is 15cm thick, the panel width ranges from 4 to 4.5 meters, and the panel height is 3.18m. The wall panels are fixed in place by means of sleeves and dowels. The design of the wall panel features four to five sleeves of 6cm diameter and 30cm depth at the bottom and the same number of dowels of 2cm diameter and 15cm length at the top. The hollow-core slabs are produced with dimensions of 1.2m width, 20cm thickness, and 2.2m–7m length. The hollow-core slabs can be saw-cut to the required length and width in the production plant to make the necessary adjustments for ending hollow-core slabs. The hollow-core slabs can be stored in site by stacking up the numbered units in a horizontal position according to the required sequence of erection, whereas the wall panels need costly special panel racks and thus are erected off-trailer.

The erection of OSP structural elements of only three residential buildings was considered for the purpose of demonstration in this study. Figure 1 shows the floor plan of a typical residential building with the wall panels numbered. Figure 2 shows the hollow-core slab layout with the hollow-core slabs, beams, and stair flights numbered. A scheme is designed to indicate work accomplishments of the project at the cut-off dates. The scheme is basically a matrix with 12 columns to represent three buildings each of three floors and roof parapet. The matrix has 254 rows comprising 81 wall panels, seven beams and 166 hollow-core slabs and stair flights for each of the three floors. The work accomplishments at any time can be indicated by filling in the appropriate cells of the matrix with 0–1 entries.

The construction engineer was interviewed and when asked to make an estimate of the number of erected OSP units a day replied that for the wall panels and parapet units the number ranges from 10 to 17 and for the hollow-core slabs, stair flights, beams and canopy the number ranges from 25 to 40. Accordingly, two statistical uniform distributions were established for the daily number of the erected wall panels and slabs.

Owing to the lack of actual data regarding the number of erected OSP units on daily basis, hypothetical uniform distributions were assumed, otherwise real statistical distributions would have been defined to reflect the type and location of the erected units. A uniform

distribution assigns equal probability to all values within the prescribed range to happen. Again, since there are no available data to support the hypothesis that different values have different possibilities of occurrence, the assumption of equal probability was made.

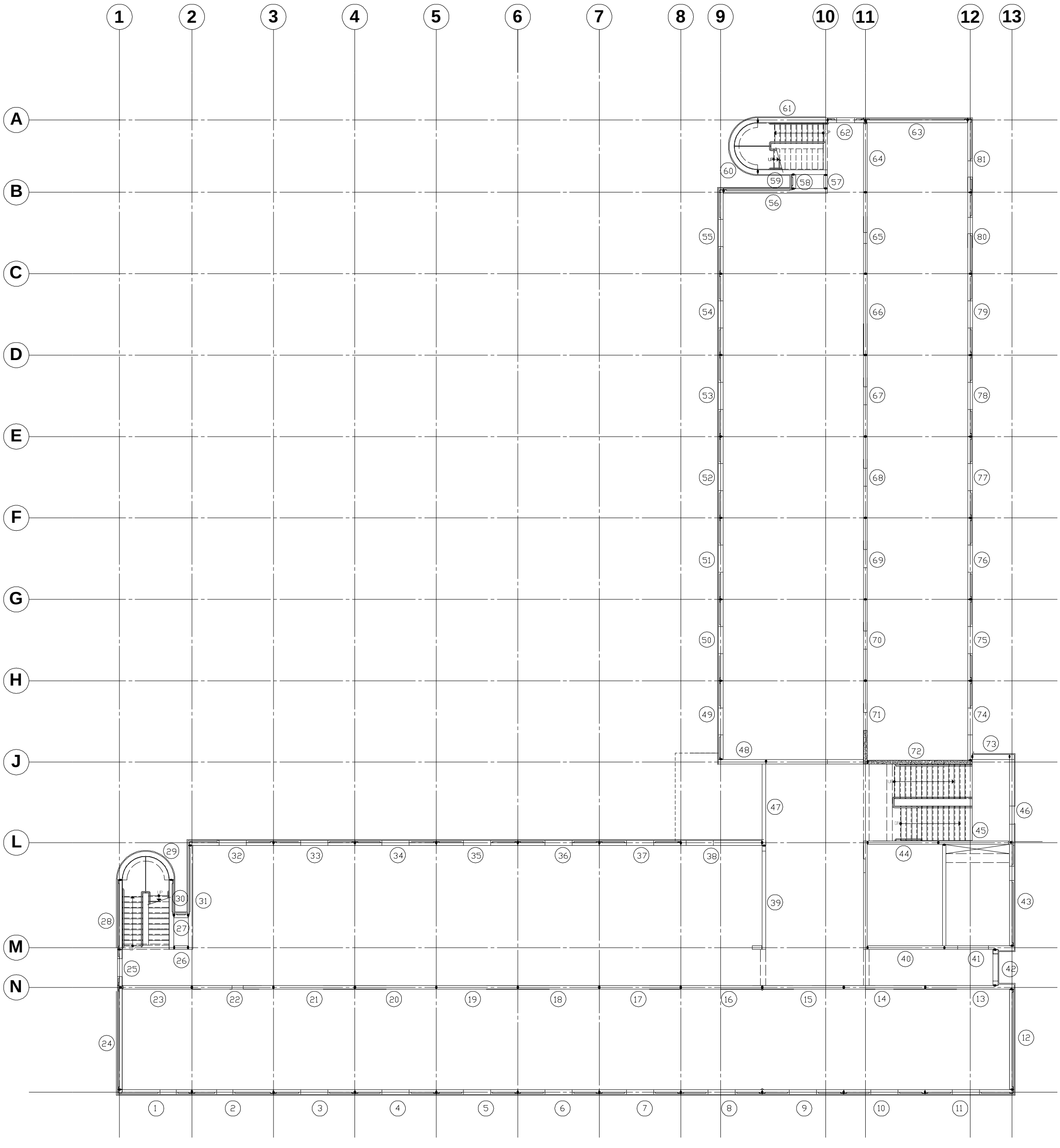


Figure 1: Floor plan of a typical residential building with the wall panels numbered

Figure 2: Hollow-core slab layout with the hollow-core slabs, beams and stair flights numbered

The erection work was simulated by randomly generating numbers to represent the erected OSP units on a daily basis using the established distributions. The appropriate cells of the matrix are filled in with ‘one’ entries following a given path of erection. The path of erection is such that wall panels of the first floor of the three buildings are erected followed by the hollow-core units of the first floor; then the work is repeated for the next two floors and finally the roof parapets. As time goes on, the number of cells with entries of ones increases to reflect the extra work that was accomplished. The simulation process was repeated 14 times to generate 14 random patterns for each cut-off date using different randomly generated numbers. Five patterns that correspond to week four are shown in Appendix I with shaded areas indicating cells with entries of ‘ones’. The five patterns feature the completion of the wall panels of the first floor of the three buildings as well as the hollow-core units, beams and stairs of the first building. The work is going on in the five patterns to erect hollow-core units, beams and stairs of the second building. It is to be noted that the variation among the generated patterns of the fourth week is basically due to the variation of the daily number of erected OSP units. The total erection time of the three buildings ranged from 20 to 21 weeks.

IMPLEMENTATION

The NN was trained using the algorithm developed by Abdel-Wahhab and Sid-Ahmed (1997). This algorithm proved to be faster and more stable than other algorithms presented in the literature. The set of data for training and testing the NN patterns constitutes 20 weeks; each week has 14 random patterns with a total of 280 patterns representing the input patterns. Since most of the random patterns of week 20 indicated project completion status, the patterns of week 21 were discarded to avoid the close similarity with the patterns of week 20. Associated with each input pattern there is an output pattern of a vector of 20 entries indicating entry of ‘one’ for the week of the pattern and ‘zero’ for the entries of the other 19 weeks. Some of the generated patterns are used for training purposes and the remaining patterns are kept for testing.

The inputs to the NN are 3048 elements representing elements of 12 columns and 254 rows and the output represents 20 weeks of the project duration. The NN was configured by changing the number of hidden layers and the number of neurons in each hidden layer. It was observed that the best performance was obtained at a configuration of one hidden layer containing 10 neurons. The NN was trained on pattern groups 1 to 10. The 10 training data were split further into two pattern groups, the first eight pattern groups and the remaining two pattern groups. The individual patterns of the eight pattern groups were used for updating the network weights and biases and were entered randomly to the neural network. The remaining two pattern groups were used for validation purposes. The validation process is a stopping criterion such that when the recognition error increases, the training session is stopped, and the weights and biases at the minimum value of error are returned. This method, which is called cross-validation, enables the generalization performance of the network to be monitored and prevents the network from overfitting the training data.

The trained NN was tested using pattern groups 11 to 14 which were not introduced to the NN during the training session. When a particular test pattern is entered to the trained network, the recognized week is the week exhibiting the highest output among the 20 weeks. The results are presented in Table 1 which indicates that the patterns of pattern groups 11 and 14 were all recognized correctly. However, two patterns of pattern group 12 and one pattern of pattern group 13 were recognized erroneously. In pattern group 12, the patterns of weeks 15 and 19 were recognized as patterns of weeks 16 and 20 respectively whereas in pattern group 13, the pattern of week 19 was recognized as pattern of week 20. However, it was observed that the NN outputs that represent the correct weeks for the three erroneous cases were slightly less than the erroneous declared weeks and the erroneous recognitions didn't exceed the next upper weeks. Generally, the NN could correctly recognize 81 members out of 84 with a recognition error of 3.6%. This low error value indicates that the proposed PR approach proved its effectiveness as a progress monitoring and evaluation technique for construction projects.

Erroneous recognitions could be attributed to the width of the ranges of the uniform distributions representing the number of precast units erected a day. The random selection from a distribution of a wide range to construct patterns of 21 weeks caused some patterns at a given week to show identical, or maybe less, work accomplishment compared to other patterns of the preceding week. This phenomenon is more likely to happen at the later weeks of the project when the effect of random selection from wide-range selection starts to build up. Through visual inspection of the patterns of the 20

Table 1: Pattern recognitions of the four test pattern groups

Week	**Test patterns**			
	Pattern 11	**Pattern 12**	**Pattern 13**	**Pattern 14**
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9
10	10	10	10	10
11	11	11	11	11
12	12	12	12	12
13	13	13	13	13
14	14	14	14	14
15	15	16*****	15	15
16	16	16	16	16
17	17	17	17	17
18	18	18	18	18
19	19	20*****	20*****	19
20	20	20	20	20

***** Erroneous recognitions

BENEFITS OF USING PR TECHNIQUE

The collection of actual data in construction sites is prone to high degree of imprecision. Russell and Fayek (1994) noted that the issue of detection in the field contains a large extent of uncertainty and inconsistency. They imputed this problem to the considerable variance in levels of education and experience as well as attitudes toward recording daily site information by field personnel. Personnel responsible for recording daily site information range from experienced and educated engineers who are willing to accurately document work progress and productivity to inexperienced and uneducated personnel who struggle hard to document daily site information. Russell and Fayek (1994) noted that the attitude of personnel is to align themselves either with the field or with the office. Those who are pro-field personnel tend to avoid paperwork. In addition, the detection of work progress by the general contractor's personnel can be biased against the subcontractors.

Another problematic attitude of field personnel is to conceal the slow progress of some activities to appear in good shape. Knowing that the actual data will be compared directly against planned data on an activity-by-activity basis, the personnel reporting actual progress tends to covert the bad performance of stumbling activities by generously reporting the actual progress. They speculate that the problems are not really serious and some remedial actions will definitely speed up progress and produce better results by the subsequent cut-off date. Another reason to conceal slow progress is that being evaluated on an activity-by-activity basis and not on the holistic project performance, the bad performance of stumbling activities will camouflage the outstanding performance accomplished in some other activities. All these problems result in a great deal of variation in the quality of information collected in the field.

The process of traditional monitoring which compares the actual collected data of individual activities against single-valued benchmarks invariably results in great variation in the quality of data collected, owing to reporting skills as well as willingness to record accurately. The generalization feature that the NN brings about offers a potential environment to overcome this problem. The PR technique generalizes a virtual benchmark to represent the whole project based on multiple possible outcomes generated at each cut-off date. The merits that the generalized benchmark offers include:

- The effect of the imprecision in data collection (which is due to either the lack of experience or the nature of the work, making it difficult to figure out the accurate amount of completed work) on the evaluation of the status of activities and the whole project is significantly diminished.
- The impetus for personnel to inaccurately report data on purpose is entirely negated as actual progress is being evaluated against a virtual benchmark.
- A fair overall evaluation of the project considering both slow-progressed and well-progressed activities is presented to the field personnel while keeping the single-valued benchmarks of the individual activities exclusively to project managers to analyse situations and make decisions.

CONCLUSION

The objective of this study was to investigate the utilization of the concept and technique of pattern recognition to monitor and evaluate progress of the OSP concrete units. The results were such that the NN could correctly recognize 81 members out of 84 with a recognition error of 3.6%. This low error value indicated that the concept and technique of pattern recognition proved effective and robust to monitor and evaluate the progress of construction projects.

ACKNOWLEDGEMENT

The first author would like to thank King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia for its continuous support and encouragement.

REFERENCES

Abd Majid, M Z, Memon, Z A and Mustaffar, M (2004) Conceptual digital monitoring model for evaluating the progress of work. *In*: *CONVR 2004: Conference on Construction Applications of Virtual Reality*, 14–15 September 2004, Lisbon, Portugal, 161–6.

Abdel-Wahhab, O and Sid-Ahmed, M A (1997) A new scheme for training feed-forward neural networks. *Pattern Recognition*, **30**(3), 519–24.

Abeid, J, Allouche, E, Arditi, D and Hayman, M (2003) PHOTO-NET II: a computer based monitoring system applied to project management. *Automation in Construction*, **12**(5), 603–16.

Barraza, G A, Back, E and Mata, F (2000) Probabilistic monitoring of project performance using SS-curves. *Journal of Construction Engineering and Management*, **126**(2), 142–8.

Blismas, N, Pasquire, C and Gibb, A (2006) Benefit evaluation for off-site production in construction. *Construction Management and Economics*, **24**, 121–30.

Cheng, M and Chen, J (2002) Integrating barcode and GIS for monitoring construction progress. *Automation in Construction*, **11**(1), 23–33.

Hiroshi, N, and Nobuoh, H (1993) Filing of construction photos linked with database. *In*: *The 5th International Conference on Computing in Civil and Building Engineering*, 7–9 June 1993, Anaheim, California. ASCE, Vol. 1, 718–21.

Kubicki, S, Halin, G and Bignon, J C (2004) Assistance to building construction coordination by image. *In*: A Dikbas and R Scherer (Eds.) *ECPPM Conference*, Istanbul, Turkey.

Memon, Z A, Abd Majid, M Z and Mustaffar, M (2005) An automatic project progress monitoring model by integrating auto CAD and digital photos. *In*: *The International Conference on Computing in Civil Engineering*, 2005. ASCE, 1605–17.

Nassar, K M, Gunnarsson, H G and Hegab, M Y (2005) Using Weibull analysis for evaluation of cost and schedule performance. *Journal of Construction Engineering and Management*, **131**(12), 1257–62.

Poku, S E and Arditi, D (2006) Construction scheduling and progress control using geographical information systems. *Journal of Computing in Civil Engineering*, **20**(5), 351–60.

Riley, D and Whitesides, J (1999) Implementing digital image photography in the building industry. *Journal of Construction Education*, **4**(2) 162–74.

Russell, A and Fayek, A (1994) Automated corrective action selection assistant. *Journal of Construction Engineering and Management*, **120**(1), 11–33.

IMPROVING TIME MANAGEMENT OF CONSTRUCTION PROJECTS

Jasper Mbachu[1]

Institute of Technology & Engineering, College of Sciences, Massey University, PO Box 756, Wellington, New Zealand

Time overruns besetting the global construction industry have negative consequences, including client dissatisfaction. Empirical surveys were carried out on the key constraints to effective time management and ways of improvement. The surveys involved registered members of the CIOB Southern Africa. Responses were analysed using multi-attribute method. Results revealed controllable and uncontrollable sources of constraints to effective time management. Constraints within the project team's control emanate from: contractors, subcontractors and suppliers; clients; consultants; and project characteristics. The most profound ways in which each source impacts negatively on effective time management are as follows. Contractors, subcontractors and suppliers: poor financial management and the associated cash flow problems. Clients: frequent changes to the scope of work. Designers: poor needs assessment and lack of foresight. Cost consultants: inaccurate estimation and pricing. Management consultants: poor strategic and risk management. The most influential uncontrollable set of constraints comprises government/statutory controls, chiefly, rules and regulations that impact on construction resources and progress. Overall, minimizing late changes through adequate briefing and feasibility studies was recommended as the most effective means by which the project team could improve time management in the construction industry.

Keywords: construction planning, contract administration, project management, project performance, scheduling.

INTRODUCTION

Time is probably the most valuable asset available to people and organizations. The guide to the Project Management Body of Knowledge (PMBOK) (PMI 1996) expresses project time management as the processes required to ensure on-time completion of the project. Time management in this context includes activity definition, sequencing and duration estimation, and schedule development and control. Since decisions made at the outset of a project are most crucial to a successful outcome (Rowlinson 1999), good time management should commence at the outset of a project development, and should include feasibility assessment, planning, scheduling, organizing, coordinating, monitoring and control of the implementation of construction projects within the constraints of available resources, and the internal and external environments within which the project is to be conceived and completed.

Effective and efficient time management of construction projects has been found to hold benefits for organizations and the construction industry in many respects (Nkado 1992; Cooke and Williams 1998; Chege and Rwelamila 2000; Bowen *et al*. 2002; Mbachu and Nkado 2007). For instance, Nkado (1992) argues that construction time

[1] j.i.mbachu@massey.ac.nz

performance is a basis for evaluating the success of a project and the efficiency of the project organization. In addition, Chan and Kumaraswamy (1998) observe that completing projects on time is symbolic of an efficient construction industry. Nkado (1992), Raftery (1999) and Mbachu and Nkado (2006) concur that the basic expectation of the client in respect of fulfilling the development needs and objectives is, essentially, receiving the project at the desired quality level, in the desired time frame and at the minimum cost compatible with this. This means that on-time project delivery is at the heart of client satisfaction, and is the bulwark upon which the confidence reposed in the project team is anchored.

Efficient time management has been a thorny issue in the global construction industry. Evidence abounds to suggest that time overrun is the norm (Alkass *et al*. 1996; Ogunlana *et al*. 1996; Kumaraswamy and Chan 1998; Ng. *et al*. 2004; Faridi and El-Sayegh 2006). Mantel *et al*. (2001) observe that between 60% and 85% of projects fail to meet their time, cost and/or performance objectives.

The consequences of inefficient time management and the resulting delays present the key problems militating against the development and viability of global construction. Some clients, especially the owner-occupiers, do prioritize time as being the constraint of utmost importance in the procurement process, owing to the high risk of default in time management. In this connection, Turner (1990) cites an instance where an industrialist or retailer may decide to extend accommodation in order to house a new process or respond to a new marketing approach. The cost of the building may only be a small part of the total project costs whereas a delay of two or three months in construction completion may delay a new production line or a new service, and could lead to loss of orders, missed opportunities, and ultimately to a ruined reputation. Generally, poor time performance diminishes the confidence reposed in the industry and its operators by financiers, insurers and clients, resulting in high interest rates, high insurance premiums, low patronage and ultimately downturns, liquidations and bankruptcies. Perhaps this lends credence to Cormican's (1985) remarks that the '(UK) construction industry is usually the most risky of the manufacturing industry and usually at the top of the bankruptcy league' (p. xi).

Time management complications inevitably arise with a construction project that involves management and coordination of several organizations and people who are all contributing to its completion. Several factors have been associated with inefficient time management and construction delays. Mantel *et al*. (2001) list possible causes of construction project delays to include improper or inadequate planning; late subcontractor deliveries; bad weather; unreasonable deadlines; equipment failure; and complex coordination problems. Delays could also arise because of estimation errors; variations in the specifications of the project deliverables; or changes to the rules of conduct or regulatory policies under which the project had been operating, all of which alter the initial plan of the project. Faridi and El-Sayegh (2006) list the most significant causes of delays in the UAE construction industry as including preparation and approval of drawings; inadequate early planning of the project; slowness of the owner's decision-making process; shortage of manpower; and poor site supervision.

Meredith and Shafer (2002) argue that planning is the most single important element in the success or failure of a project. From this perspective, the authors add to the list of factors underlying poor time performance: multi-tasking involving switching from a task associated with one project to another task associated with a different project; misuse of time contingency or buffers; lack of clear priorities; inflation of time estimates and the fact that work tends to fill available time; and conflicts in the project team formation arising mainly from priorities and procedures. Goldratt (1997) provides further insights into the causes of poor time management: student syndrome involving delaying the start of an activity that has good float resulting in inability to deal in a timely way with hidden constraints, the assumption that activity times are known with certainty, as well as wrong assumptions about precedence relationships and resource dependencies.

Suggested ways of improving time management of construction projects could be categorized into three broad groupings of solutions: improvement of procurement systems through the choice of integrative and collaborative approaches (Latham 1994; Love *et al*. 1998; Rwelamila and Meyer 1999; Chege and Rwelamila 2000; Toukey *et al*. 2001); improvement of the planning and scheduling processes (Cormican 1985; Goldratt 1997; Cooke and Williams 1998; Mantel *et al*. 2001); and the improvement of the organization and the delivery processes through the use of innovative systems (Ng *et al*. 2004). However, a key gap in the literature was that the suggested ways of improving time management comprise a listing of causes of delays and improvement approaches without some quantification of their likely impact on the time management efforts.

This study adopts the risk management perspective in exploring ways of improving time management of construction projects. The focus was on risk identification and risk quantification. Considerable research had been undertaken in the area of construction project risks, and ways of improving efficient time management and minimizing project delays have been suggested. However, the key gap identified in the literature was that possible sources of project risks or causes of poor time performance were listed without some quantification of their likely impact on time overruns. The study contributes to filling this gap by undertaking further risk identification and quantification, and ways of improving on-time project delivery. This involved a survey of contractors and consultants in the South African building industry who were registered members of the CIOB-Southern Africa. The following sections present findings of the literature and the empirical investigations.

METHODOLOGY

Research method

The descriptive survey method was used to explore further ways of improving time management of construction projects. The focus was on identifying constraints to effective time management and suggestions for improvement. This involved questionnaire surveys conducted with contractors and consultants in the South African construction industry who were registered members of the CIOB-Southern Africa.

Data analysis

The multi-attribute method was used to analyse the ratings of the respondents with a view to establishing a representative or mean rating point for each group of respondents. The analysis drew from the multi-attribute utility approach of Chang and Ive (2002), and Mbachu and Nkado (2006). It involved the computations of the mean rating (MR_i), which indicates the representative rating for a group of respondents as to their perceived level of influence or effectiveness of each attribute within a subset. In each computation, the total number of respondents (TR) rating each attribute was used to calculate the percentage of the number of respondents associating a particular rating point to each constraint as shown in the equation below.

$$MR_i = \sum_{k=1}^{5} (R_{pki} \times \%R_{ki})$$

where: MR_i = mean rating for attribute *i*; R_{pki} = rating point *k* (ranging from 1 to 5); $\%R_{ki}$ = percentage response to rating point *k*, for attribute *i*).

Using 2.5 as the threshold of influence in a five-point rating continuum – 5 being very influential, and 1 being not influential – the MR value served to prioritize and segregate the influential and not-influential constraints, based on the combined ratings by a respondent grouping.

FINDINGS

Survey results

In total 550 questionnaires were distributed to randomly selected representative samples of respondents from the sampling frame. By the cut-off date set for the return of the questionnaires, only 187 responses were received, out of which 178 were usable. This represented an effective response rate of 32%. The discarded responses were those that did not meet the quality criteria or consistency checks used to screen the responses.

Constraints to effective time management

The results of the analysis of the survey responses reveal that improvement in time management of construction projects could be achieved by addressing constraints to effective time management in five areas (see Figure 1): the client system; consultants; project characteristics; contractors, subcontractors and suppliers; and the external constraints.

Client-related constraints

The analysis of the client-related constraints in Table 1 shows that frequent changes to the scope of the work, especially at critical stages of the implementation process, were perceived as the most influential constraints to effective time management in the construction industry. This agrees with the observations of Sutterfield *et al*. (2006) that changing the project requirements after much of the basic project planning was performed and without a corresponding change in other variables could result in an inability to effectively estimate and control project deliverables.

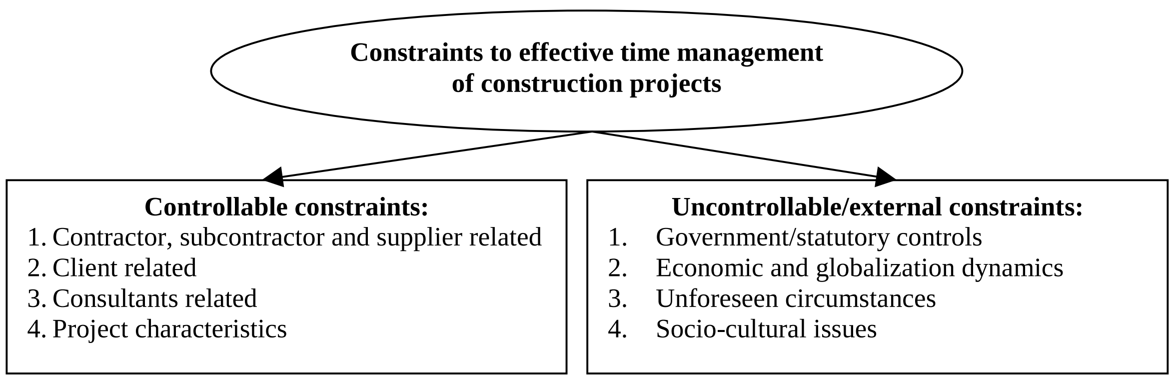


Figure 1: Broad categories of constraints to effective time management of construction projects

Table 1: Constraints to effective time management: client related

		Constraints to effective time management	VH 5 %	H 4 %	M 3 %	L 2 %	NI 1 %	TR	MR
Influential constraints: MR ≥ 2.5	1.	Frequent changes to the scope of work, especially at critical stages	39	29	24	6	2	178	3.98
	2.	Delayed or incomplete payment for works duly completed	37	34	17	9	3	177	3.93
	3.	Imposition of unrealistic deadlines	28	40	17	11	4	177	3.77
	4.	Delay in supplying required information	28	33	28	9	2	178	3.76
	5.	Insistence on preferred procurement route and contract forms, even when these are not appropriate	18	41	21	14	6	171	3.49
	6.	Impatience: not allowing sufficient time for feasibility studies, detailed design and planning before inviting tenders	17	21	44	14	4	173	3.33
	7.	Unclear scope of work: inability to comprehensively articulate and communicate project needs and requirements	29	17	34	21	5	175	3.32
	8.	Insistence on lowest tender as sole criterion for contract award	14	32	37	15	5	175	3.30
	9.	Insufficient funding to ensure progress and timely completion	11	26	35	17	10	176	3.11
	10.	Undue interference at construction stage	7	10	35	23	25	173	2.51
	11.	Void in project management responsibility: inability to delegate authorities for decision making; inexperience; lack of project management knowledge	6	17	21	33	23	174	2.49

*Levels of influence: 5 = Very high (VH); 4 = High (H); 3 = Moderate (M); 2 = Low (L); 1 = Not influential (NI). TR = Total number of respondents; MR = Mean rating.

Project characteristics

Constraining influences of the project characteristics were analysed as in Table 1; Table 2 summarizes the results. Project complexity, innovation/uniqueness, buildability issues and specification problems, all constitute the most influential project characteristics that impact negatively on time management. Shimizu and Hitt (2004) partly confirm this by observing that if specifications are not clear, inconsistent or incomplete, they become a source of uncertainty and risk which could undermine on-time project delivery.

Table 2: Constraints to effective time management: project characteristics

1.	Project complexity; innovation/uniqueness; design/buildability; specifications
2.	Difficulties arising from project size/scope of work
3.	Strategic importance of the project and the accompanying levels of expectations; number of stakeholders; conflicts of interests
4.	Site characteristics/environmental constraints: sub-soil conditions, terrain, hazards, underground services, etc.
5.	Site location: access, site restrictions, traffic congestion, parking space, services/infrastructure
6.	Availability of technology/resource requirements: labour, capital, plant, materials
7.	Social, environmental, statutory, legal, political or planning requirements for the type of project

Consultants' influences

The consultants' influences constraining efficient time management were analysed in Table 1; Tables 3–5 summarize the key constraints. Designers' most constraining influences were associated with poor needs assessment, including inability to comprehensively articulate clients' needs and requirements and foresee future changes. This result is not surprising, as without proper briefing and feasibility analysis, the planning will be based on inadequate information. In this context, Kerzner (2003) argues that good upfront planning may reduce the number of changes required in the project.

For the cost consultants, inaccurate estimation and pricing owing to the use of generic or outdated cost information was perceived as having the worst influences on time management. Perhaps the key issue here is the fact that contractors often use estimates provided by the cost consultants as benchmarks for expenditure and schedule controls (Cooke and Williams 1998). Inaccurate benchmarks would obviously lead to undesirable outcomes, including delays.

In Table 5, it was shown that poor strategic and risk management, failure to scan and respond proactively to the external environment, and inadequate contingency plans, all add up as the most profound ways in which management consultants could contribute to constrain effective time management. The next in importance is poor scope definition and management of scope creep, both of which fall within change management. Kerzner (2003) lends credence to these results by asserting that, 'if changes are unmanaged, then more time and money are needed to perform risk management, which often takes on the appearance and behaviour of crisis management' (p. 695).

Table 3: Constraints to effective time management: design consultants related

1.	Poor needs assessment: inability to comprehensively articulate client's needs and requirements and foresee future changes
2.	Delays in confirming instructions or supplying information required
3.	Buildability problems: designs not compatible with contractor's methods and equipment
4.	Design ineffectiveness: failure to sufficiently address client's needs and preferences, resulting in frequent and often covert revisions
5.	Insufficient details in project documentation
6.	Design/detailing errors and accompanying frequent revisions
7.	Poor/incorrect specifications and not taking responsibilities for errors or omissions
8.	Lack of flexibility in design to efficiently accommodate client changes
9.	Multi-tasking: being involved in too many jobs at the same time

Table 4: Constraints to effective time management: cost consultants related

1.	Inaccurate estimation and pricing mainly due to use of generic/outdated cost information
2.	Inaccurate or biased valuation of works, payments and claims, resulting in disputes
3.	Lack of knowledge of contractor's construction methods and equipment, resulting in cost management processes that are in conflict with contractor's expectations, and the associated animosities
4.	Lack of knowledge of broader issues affecting project costs resulting in invalid or unreliable cost advice
5.	Errors/omissions in bills of quantities
6.	Unprofessional conducts, especially being biased towards the client to the detriment of the contractor
7.	Lack of knowledge and experience in the methods of dispute resolutions and conflict management

Table 5: Constraints to effective time management: management consultants related

1.	Poor strategic and risk management, failure to scan and respond proactively to external environment; inadequate contingency plans

2.	Poor scope definition and management of 'scope creep'; poor change management
3.	Inadequate supervision, control and monitoring of contractors and works progress; inadequate visits to site
4.	Poor planning, forecasting/budgeting, organization and coordination of the project team and resources
5.	Weak project teams; lack of motivation and synergy
6.	Poor leadership owing to lack of technical and managerial skills/experience
7.	Poor communication and relationship management, especially inability to deal with conflicting organizational cultures
8.	Poor understanding and translation of client requirements owing to lack of clear understanding of client's business and overall strategic objectives for the project

Contractors', subcontractors' and suppliers' influences

Contractors', subcontractors' and suppliers' influences constraining effective time management were analysed as in Table 1, and summarized in Table 6. For the contractors and subcontractors, cash flow problems arising from lack of fiscal discipline, and lack of creditworthiness with suppliers and lenders, exert the most negative influences on on-time project delivery. On the other hand, delays in the supply of materials, components and equipment constitute the suppliers' worst influences on on-time project delivery efforts. This result agrees with the findings of Faridi and El-Sayegh (2006), that delays by suppliers are significant factors causing delays (in the UAE construction industry).

Table 6: Constraints to effective time management: contractor, subcontractor and supplier related

	Contractor and subcontractor related
1.	Cash flow problems: poor financial management/lack of fiscal discipline; lack of creditworthiness with suppliers and lenders resulting in inability to raise funds to complete the project on schedule, as well as delayed payments to subcontractors and suppliers
2.	Low productivity owing to inadequate motivation of workforce, use of ineffective methods and equipment, poor workmanship and abortive works
3.	Lack of proper coordination of own workforce and subcontractors; inadequate supervision, monitoring and control
4.	Poor planning, budgeting and scheduling; inadequate risk management and contingency plans
5.	Over capacity: handling too many jobs at the same time
6.	Lack of technical and managerial competencies; lack of experience on current job
7.	Inability to manage employer's changes/variation orders effectively
8.	Disruptions, costs and delays due to contractual disputes; adversarial relations, court/arbitration cases; poor relationship management; attitude to service
9.	Poor management of occupational safety and health issues, resulting in costly and disruptive accidents and associated penalties
10.	Shortage of skilled workforce; inability to attract and retain skilled workers
11.	Underbidding; cutting corners to save costs, tendering errors, frivolous claims
	Supplier related
1.	Delays in the supply of materials, components or equipment
2.	Supply of defective or incomplete materials/components
3.	Insistence on upfront payments; unwillingness to deliver to some areas
4.	Misunderstanding of material specifications and associated errors in supplies

Uncontrollable constraints

The identified uncontrollable constraints to effective time management were analysed as in earlier tables. The results are summarized in Table 7. The most influential in this grouping is a set of government/statutory control mechanisms comprising rules and regulations impacting on construction resources and progress, legal/statutory controls and overly prescriptive and overbearing enforcements.

Table 7: External/ uncontrollable sources of constraints to effective time management

1.	Government/statutory controls: rules and regulations impacting on construction resources and progress: monetary/fiscal policies (level of infrastructure spending, taxation, import restrictions, lending rates, etc.); legal/statutory controls (delays in giving project approvals by local authorities; town planning laws; permits/licensing; frequent amendments to existing policies); regulatory framework (building regulations, too prescriptive and overbearing enforcement of regulations such as OSH, etc.)
2.	Economic and globalization dynamics: delays arising from constraints on resources and demoralization due to volatility of exchange rate, inflation, interest rates, energy crises, demand and supply levels, etc.
3.	Unforeseen circumstances: delays arising from destructions and/or stoppages associated with site accidents, inclement weather conditions, natural hazards, etc.
4.	Socio-cultural issues: delays arising from stoppages, and demoralization due to industrial action, health issues (cancer; HIV/AIDS), socio-cultural attitude to work, alcoholism, absenteeism, vandalism, socio-cultural conflicts, disputes and racial tensions, xenophobia, etc.

Relative levels of influences of the broad categories of constraints

The relative levels of influences of the broad categories of constraints to effective time management were analysed in Table 8. The most influential grouping was perceived to be that of contractor, subcontractor and supplier related constraints. However, this result contrasts with earlier findings of Mbachu and Nkado (2006) who see this group of service providers as mere instruction-takers who must comply with the directives and supervisions of the consultants – the main group responsible for piloting the project to successful outcomes. The mean ratings of all five groupings were above 2.5, implying that they were perceived to exert significant influences on time management of construction projects. This finding concurs with earlier results – Faridi and El-Sayegh (2006) and Mbachu and Nkado (2007) – who adopted a similar pattern of classifying factors constraining successful project outcomes.

Table 8: Relative levels of influences of the broad categories of constraints to effective time management

		Broad categories of constraints to effective time management	Levels of influence*						
			VH	H	M	L	NI		
			5	4	3	2	1		
			%	%	%	%	%	TR	MR
Influential: MR ≥2.5	I.	Contractor, subcontractor and supplier related	34	39	24	1.7	1	178	4.03
	II.	Client related	25	39	32	1.1	3	178	3.82
	III.	Consultants related	3	24	24	41.0	7	178	2.75
	IV.	Project characteristics	2	8	57	26.0	7	177	2.72
	V.	External/uncontrollable factors	1	11	35	42.9	10	177	2.51

*Levels of influence: 5 = Very high (VH); 4 = High (H); 3 = Moderate (M); 2 = Low (L); 1 = Not influential (NI). TR = Total number of respondents; MR = Mean rating

Suggested ways of improving time management

Respondents made further suggestions on how to improve time management in the construction industry. The relative levels of effectiveness of the suggested ways were analysed as before; Table 9 summarizes the results. The most effective strategy was perceived to be minimization of the late changes by clients and consultants through adequate briefing and feasibility studies. This lends credence to the observations of Rowlinson (1999), that decisions made at the outset of a project are most crucial to a successful outcome. It is therefore perceived that by carrying out proper briefing and feasibility studies, clients' and users' future changes could be predicted and addressed in the design. This would go a long way to reduce the preponderance of client changes at critical stages of the project implementation and ultimately to on-time project delivery.

Table 9: Suggested ways of improving time management in the construction industry

1.	Minimize late changes by clients and consultants through adequate briefing and feasibility studies
2.	Effective planning: adequate time should be allowed for proper planning and verification of key facts at the outset
3.	Minimize cash flow problems by making sure that adequate funds are available before the commencement of the project, and that works duly completed are promptly paid for
4.	Award of contract should be based on capability, rather than lowest tender
5.	Team work should be engendered through proper coordination and communication, trust, openness, and emphasis on fairness and win-win outcomes
6.	Adequate project supervisions by both project managers and contractors
7.	Consultants should prepare detailed and complete contract documentations before calling for tenders
8.	Provide easy access to project finance for contractors, especially the SMEs; more government assistance in providing contract guarantees
9.	Continuous training and development of the workforce

CONCLUSION

The key gap identified in the literature was that possible sources of project risks or causes of poor time performance were listed without some quantification of their likely impact on time overruns. This study contributes to filling this gap by undertaking empirical investigations to identify further priority constraints to effective time management and ways for improvement, as well as the analysis of their relative levels of impact. The results reveal two broad categories of constraints to effective time management of construction projects: constraints within the project team's control (emanating from contractors, subcontractors, suppliers, clients, consultants and project characteristics), and external constraints. Under each source, the most profound ways in which effective time management could be constrained are listed as follows. Contractors, subcontractors and suppliers: cash flow problems due mainly to poor financial management/lack of fiscal discipline, and lack of creditworthiness. Clients: making frequent changes to the scope of the work, especially at critical stages of the implementation process. Designers: poor needs assessment, i.e. inability to comprehensively articulate clients' needs and requirements and foresee future changes. Cost consultants: inaccurate estimation and pricing due to the use of generic or outdated cost information. Management consultants: poor strategic and risk management approaches, including failure to scan and respond proactively to external environment and having inadequate contingency plans.

In the order of significance of influence on time management, the groupings of constraints which are outside the project team's control comprise the government/statutory controls, economic and globalization dynamics and unforeseen circumstances. Overall, minimizing late changes made by clients and consultants through adequate briefing and feasibility studies was recommended as the most effective means by which the project team could improve time management in the construction industry.

ACKNOWLEDGEMENT

The author wishes to thank Ernest Yeboah-Acheampong of the School of Construction Economics and Management, University of the Witwatersrand, Johannesburg, for his assistance in the second phase of the questionnaire surveys.

REFERENCES

Alkass, S, Mazerolle, M and Harris, F (1996) Construction delay analysis techniques. *Construction Management and Economics*, **14**(1), 375–94.

Bowen, P A, Hall, K A, Cattell, K S, Edwards, P J and Pearl, R G (2002) Perceptions of time, cost and quality management of building projects. *Australian Journal of Construction Economics and Building*, **2**(2), 48–56.

Chan, D and Kumaraswamy, M (1997) A comparative study of causes of time overruns in Hong Kong construction projects. *International Journal of Project Management*, **15**(1), 55–63.

Chege, L W and Rwelamila, P D (2000) Risk management and procurement systems – an imperative approach. *In*: A Serpell (Ed.) *CIB W92 Proceedings: 'Information and Communication in Construction Management' Procurement Systems Symposium, 2000*, Pontificia University Catolica de Santiago, 373–86.

Cooke, B and Williams, P (1998) *Construction planning, programming and control*. London: Macmillan Press.

Cormican, D (1985) *Construction management planning and finance*. London: Longmans.

Faridi, A S and El-Sayegh, S M (2006) Significant factors causing delays in the UAE construction industry. *Construction Management and Economics*, **24**(11), 1167–76.

Goldratt, E M (1997) *Critical chain*. Great Barrington, MA: North River Press.

Kumaraswamy, M M and Chan, D W M (1998) Contributors to construction delays. *Construction Management and Economics*, **16**(1), 17–29.

Latham, M (1994) *Constructing the team: joint review of procurement and contractual arrangements in the United Kingdom construction industry: final report*. London: HMSO.

Love, P E D, Skitmore, M and Earl, G (1998) Selecting a suitable procurement method for a building project. *Construction Management and Economics*, **16**, 221–33.

Mantel, S J J, Meredith, J R, Shafer, S M and Sutton, M M (2001) *Project management in practice*. New York: John Wiley & Sons, Inc.

Mbachu, J I C and Nkado, R N (2006) Conceptual framework for assessment of client needs and satisfaction in the building development process. *Construction Management and Economics*, **24**(1), 31–44.

Mbachu, J I C and Nkado, R N (2007) Factors constraining successful building project implementation in South Africa. *Construction Management and Economics*, **25**(1), 39–54.

Meredith, J R and Shafer, S M (2002) *Operations management for MBAs*. 2ed. New York: John Wiley & Sons, Inc.

Ng, S T, Skitmore, M, Deng, M Z M and Nadeem, A (2004) Improving existing delay analysis techniques for the establishment of delay liabilities. *Construction Innovation*, **4**(1), 3–17.

Nkado, R (1992) Construction time information system for the building industry. *Construction Management and Economics*, **10**(1), 489–509.

Ogunlana, S O, Promkuntong, K and Vithool, J (1996) Construction delays in a fast-growing economy: comparing Thailand with other economies. *International Journal of Project Management*, **14**(1), 37–45.

PMI (1996) *Guide to the project management body of knowledge*. North Carolina: Project Management Institute.

Raftery, J (1999) Quasi-rational behavior in the property and construction market. *Construction Management and Economics*, **17**(1), 21–7.

Rowlinson, S (1999) A definition of procurement systems. *In*: S M Rowlinson and P McDermott (Eds.) *Procurement systems: a guide to best practice in construction*. London: E & FN Spon.

Rwelamila, P D and Meyer, C (1999) Appropriate or default project procurement systems. *Cost Engineering*, **41**(9), 40–4.

Toukey, J E, Murray, M, Hardcastle, C and Langford, D (2001) Construction procurement routes: re-defining the contours of construction procurement. *Engineering, Construction and Architectural Management*, **8**(1), 20–30.

Turner, A (1990) *Building procurement*. London: Macmillan Education Ltd.

CONSTRUCTION COORDINATION FUNCTION – A PERSPECTIVE BASED ON THE ‘STACEY DIAGRAM’

D. Darshi De Saram,[1] Pradeep G. Chettri[1] and Paul W. Fox[2]

[1]*Department of Construction Management and Engineering, North Dakota State University, Fargo, North Dakota 58105, USA*
[2]*Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong*

The critical incident technique (CIT) was used in this study to gather qualitative data on quality aspects of construction coordination. As a first step in sorting the data, 82 critical incidents were mapped on the Stacey Diagram. The result indicates that incidence of negative incidents is low at the bottom of the diagram, where there is high agreement among the parties to an issue in question. Possibly, the way construction projects are managed, practitioners are better prepared to make judgmental decisions required in these situations. Conversely there is much greater incidence of negative incidents at the top of the diagram, where there is low agreement among the parties to an issue in question. This maybe an indication that construction practitioners are less equipped to handle matters of organizational dynamics required either to align the parties concerned or to arrive at a compromise.

Keywords: complexity, coordination, critical incident technique (CIT), organizational dynamics, site operations.

INTRODUCTION

Construction coordination is found to be a very complex function with a vast scope of activities. Chitkara (1998) and Martin (1976), state that a project manager has to carry out planning, organizing, staffing, directing and controlling. Chitkara (1998) further modifies these duties to suit the construction project environment as planning, organizing, procuring, leading and controlling. Then he states that common to all these functions is the function of coordination. It is noticeable that most duties and responsibilities of a construction project manager contribute to achieving coordination. Walker (1996) states:

> It is clearly the case that success of the construction process depends to a large extent upon the way in which the architect, engineer, quantity surveyor, contractors and others work together. It depends upon them perceiving the same objectives for the project and recognising that what each of them achieves depends upon what the others do. With this view they should be able to stand above the particular interests of their own contribution and see the problem posed by the project as a whole. The advent of the project manager has, to a large degree, come about as a result of the inability of the contributors to consistently achieve this and in response to the consequent need for someone to concentrate solely upon integrating the various contributors in the interest of the client.

[1] darshi.desaram@ndsu.edu

Crichton (1966) has described the reality in a construction site as a social system in which ‘a group of people are systematically sharing control of a common process, where the relationships among the group are based on mutual independence and contributions to the common task are based on sequential finality’. He further states that this system ‘does not seem suited to effectively control a process characterized by interdependence of operations, fraught with uncertainty, requiring carefully phased decisions and continuous application of all control functions’. In such a context, ‘coordination is essential both within and among the various departments to fill up the voids created by changing situations in the systems, procedures and policies … coordination is one of the most sensitive functions of the management’ (Chitkara 1998).

There are reasons that make it difficult for industry practitioners and researchers to align the construction coordination function with the ‘classic’ quality improvement models of total quality. Tenner and DeToro (1992) have indicated that it is difficult to apply the ‘classic’ tools of total quality to service processes that are characterized by low degree of repetition (low repetition), intangibility and high customer participation in the processes themselves (co-production). Further, Crichton (1966) points out that coordination in the building industry is carried out quite informally. De Saram (2002) observed that the two characteristics of the coordination processes: (1) customers not actually soliciting the service (unsolicited service); and (2) the problem-solving nature of the coordinators’ work also make it difficult to manage construction coordination as a systematic service process.

Possibly because of such reasons, construction coordination function remains under-researched. In this context, De Saram (2002) presents an argument that multi-attribute quality measurement methods are not suitable for measuring the quality of the construction coordination function and proposes the critical incident technique (CIT) as a more effective method.

This paper presents a part of an investigation that was carried out to explore the value of applying the critical incident technique (CIT) to the construction coordination function, in particular to see if coordination quality can be measured effectively through the technique. Over 100 critical incidents (defined below) of construction coordination were collected from site personnel in a number of countries of Asia and North America. On sorting and cataloguing the incidents collected, a significant difficulty was encountered in using ‘coordination processes’ as one level of classification. The results appeared to vindicate the statement by Schön (2002): ‘Artistry is not reducible to the exercise of describable routines’. To overcome this hurdle, and to carry out the classification in a meaningful way, an attempt was made to map the critical incidents on the ‘Stacey Diagram’ (introduced below). The mapping thus revealed a different perspective of the construction coordination function. In most industries, coordination is seen as a function requiring technically rational management. This segment of the research examines how the construction coordination function maps outside the area of certainty.

OBJECTIVE OF THE RESEARCH

The objective of the research presented is to: map critical incidents of construction coordination on the ‘Stacey Diagram’, so as to enable construction practitioners to be better informed in selecting management methods they may apply.

CRITICAL INCIDENT SORTING IN PREVIOUS RESEARCH

Another significance of this research is that the exercise of mapping on the Stacey Diagram could be considered as a meaningful way to sort critical incidents, departing from paths taken by previous research applying CIT in a number of other studies. In many previous research studies using CIT that were available for review, critical incidents were sorted into various categories as given in Table 1. Because of the very wide scope of the coordination function, attempts to adopt similar techniques to decide on sorting categories yielded too many categories and subcategories to be useful. In this context it was anticipated that mapping critical incidents on the Stacey Diagram would not only be a meaningful way of sorting, but would also reveal a new perspective of this complex and less tangible function.

Table 1: Sorting critical incidents in previous research

Publication	Method	No. of categories
Smith and Kendall (1963)	Qualities or characteristics to be evaluated (by sorting the incidents) were listed by the team performing analysis and further refined over an iterative procedure	9
Fineman and Payne (1973)	Sorted by each of the researchers independently into apparent clusters	7
Campbell *et al.* (1973)	Sorted into what appeared to be homogeneous categories and further refined during discussions held as analysis progressed	10
Latham and Wexley (1977)	Incidents which describe essentially the same behaviour were grouped into one cluster	78
Hamlin and Reidy (1997)	Subjectively classified and clustered	8

THE STACEY DIAGRAM

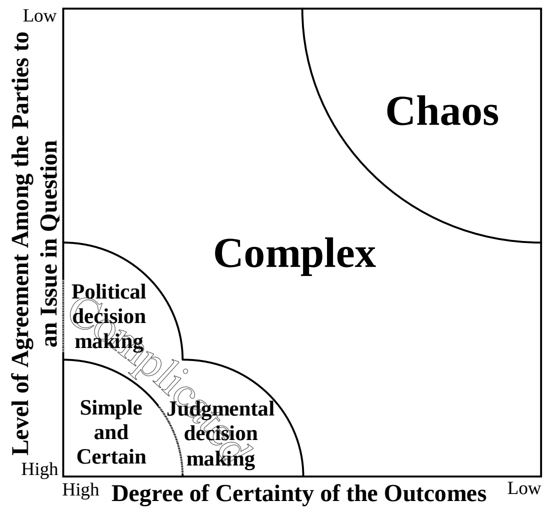


Figure 1: The Stacey Diagram (Zimmerman 2001)

The ‘Stacey Diagram’ (Zimmerman 2001), also known as the ‘Landscape Diagram’ is based on two perpendicular axes representing the degree of certainty of the outcomes and the level of agreement among the parties to a management issue in question (see Figure 1). In the quadrant thus formed, the area adjacent to the lower left corner represents issues of greater certainty to which the technically *rational* management may be applied, where most scientific and engineering management theories are focused. The area adjacent to the opposite (upper right) corner represents *chaos*, a condition most managers and researchers may wish to avoid. When moving away from the lower left corner, one first encounters a zone where, as shown in Figure 1, management begins to become complicated requiring *judgmental* decision making (more in the direction of the horizontal axis) and *political* decision making (more in the direction of the vertical axis). In between the zones described so far, there is a large area, stretching from the upper left corner of the quadrant to the lower right corner, where dynamics of *complexity* are more significant. In this region, the self-organizing and evolving nature of organizations becomes more visible and concepts of complexity become significantly applicable.

The Stacey Diagram, as discussed above, is a perspective of how different management approaches maybe interrelated. Construction coordination, being a complex and diverse function requiring diverse management approaches, may map into various areas of this diagram.

USE OF THE CRITICAL INCIDENT TECHNIQUE TO STUDY CONSTRUCTION COORDINATION

Stauss (1993) further states that the CIT is essentially a means of assembling and classifying stories or ‘critical incidents’ by employing content analysis, and that Flanagan originally developed this method in 1954 to identify requirements for effective job performance. He defined an incident as ‘any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act’, and is called critical ‘if it makes a “significant” contribution, either positively or negatively, to the general aim of the activity’. Thus, CIT focuses on events that have been ‘seen to lead to success or failure in accomplishing a task’ (Stauss 1993).

Stauss (1993) states that a survey of critical incidents involves two questioning steps. The first requests a ‘comprehensive description of the incident in the customer’s own words’, followed by a query as to ‘which circumstances were decisive for the customer’s evaluation’. Based on these guidelines and taking the survey described in Bitner *et al.* (1990) as an example, the very simple set of two questions was developed, as described below:

> Think of a time when, as a construction project participant (at the construction stage), you met with a particularly satisfactory (or unsatisfactory) incident of site coordination by the main contractor.
>
> 1. How exactly did the incident happen? (Need not disclose the names of the site or companies or individuals involved. Use their designations only, e.g. client, main contractor, project manager, site engineer, QS.)
> 2. What actions in that incident exactly made you feel satisfied (or dissatisfied)?

Our inquiry was not focused on any particular site, because this might create both a lack of willingness to furnish information and a lack of confidence to supply authentic information, and it was decided to collect data only from industry personnel who were volunteering to participate. Therefore, as evidenced by the first question above, the respondents were made to feel comfortable by allowing the critical incidents described to be unattributable. Nevertheless, it was necessary to establish the type of stakeholder responding to the survey, and a third question was therefore asked as follows:

3. In that site, what was your position?
   ……………………………………………… working for the Client/Consultant/Main Contractor/ Other (please specify) …………

   (Delete inapplicable)

Over 100 critical incidents of construction coordination were collected from site personnel in a number of countries of Asia and North America.

MAPPING CRITICAL INCIDENTS ON THE STACEY DIAGRAM

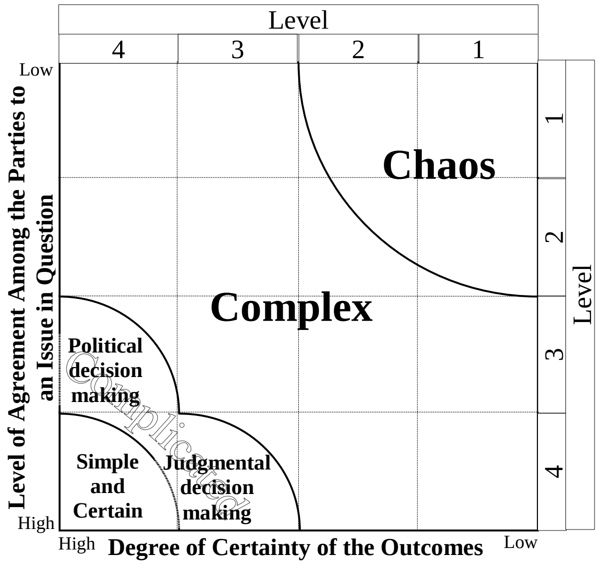


Figure 2: The Stacey Diagram showing four broad levels along each axis

A total of 82 critical incidents were mapped on the Stacey Diagram. As the critical incident survey collected qualitative data, it was necessary for the researchers to analyse each incident and decide how they map on the diagram. The procedure was to read each incident carefully and decide:

1. what degree of certainty of the outcomes (along the horizontal axis); and
2. what level of agreement among the parties to an issue in question (along the vertical axis)

is reflected. After careful analysis, critical incidents were categorized into four broad levels from 1 to 4 (1 being the lowest and 4 being the highest) along each axis as indicated in Figure 2. To illustrate this process of categorization, four examples are given below.

Example 1

Critical Incident No. 0003

Responding stakeholder: Client

> There are instances where the contractor has to make floor penetrations of sizes ranging as small as 50–75mm to as big as 300mm. The contractor will miss out – human beings – so end up needing coring. In some areas, if you miss out, coring will not be possible due to the structural concept – the structural engineer will say you cannot core within 600mm of the column.
>
> Here [in that site] they missed a row of penetrations for rainwater down pipes. They were next to the columns and as a result they wanted to go through a point 600mm away. If they were going through the original location they could have made a neat and small 150mm box-out next to the column. Now they would need a huge box-out. I refused because the furniture will not fit in anyway and it is an utter waste of space – some 750mm just for a rain water pipe! I wanted the rain water system to be redesigned and the architect came with a scheme that was not all that nice.
>
> I am dissatisfied because it was a terrible mistake. It is very difficult to correct. There are so many people out there [onsite] to check these things and coordinate.

In the above critical incident, the mistake appears to be genuine. The contractor appears to have had every intention of making the floor penetrations as designed. The level of agreement among the parties to the issue in question (along the vertical axis) could hence be considered as very high, i.e., ‘Level 4’. On a construction site, this is usually an activity watched by many pairs of eyes, hence, the degree of certainty of the outcomes (along the horizontal axis) is very high, i.e. ‘Level 4’, although it had failed this time. This incident would, as a result, map on to the region close to the bottom left corner of the Stacey Diagram, where the management approach is considered simple and certain.

Example 2

> Critical Incident No. 0007
>
> Responding stakeholder: Executive Engineer (working for the client)
>
> Because we are working close to an MRT [underground railway (Singapore)] reserved line there are certain load restrictions that are imposed at certain locations of the construction site. Initially, there were some overloading issues where they stockpiled too much debris at certain sensitive areas. Having informed them on this and requested to enforce stricter control, some initiative the contractor took was to, besides just imposing the controls, put up flag lines, printed and put up placards indicating certain demarcation zones, at certain locations defining clearly what the loading requirements are.
>
> These are the initiatives contractors took though we did not really expect. I think these are good controls.

In the above critical incident, the contractor’s management shows a genuine commitment to prevent overloading the ground at the sensitive locations of the site. Hence the agreement among the parties to the issue in question (along the vertical axis) could be considered as very high, i.e. ‘Level 4’. The degree of certainty of the outcomes (along the horizontal axis) was categorized as ‘Level 2’ because there is the risk of site operatives making a mistake.

Example 3

> Critical Incident No. 0015
>
> Responding stakeholder: Quantity Surveyor
>
> It was a measure and pay contract and a huge site where they were constructing many buildings, concrete aprons, services, roads and so on. Contractor was laying external water and sewage mains. Usually they will excavate a trench of sufficient length for laying 3 or 4 six-metre lengths of pipe. Then, they lay the pipe and backfill with a minimum sand cover of 150mm. Backfilling is done immediately after the laying of the pipe to avoid the danger of the PVC pipe getting displaced if it rains and the trench gets flooded. However, this process takes around a day, during which my staff take the measurements. The problem happened when the contractor had to do a 100mm water supply branch line to a remote corner of the site. The length of the branch was nearly 100m long – a job that would have taken maybe three days at their normal pace. However, the ground was found to be extremely sandy and starting the work after lunch one day, they had excavated the entire length of the branch in maybe couple of hours. The specification was that the minimum width of a trench was to be 600mm. However, because of the very sandy conditions and because of the absence of rocks or any foreign matter, the consultant had not insisted on the sand cover and allowed them to lay the pipe in a just 300–400mm wide trench and use some of the excavated material itself in the cover. Being just a 100mm pipe, they had very easily fitted it and the whole job was over by the end of that day. Being a very large site my staff have not been aware of this rapid progress and were not there to take the measurement. Nobody cared to inform us to take the measurements. Usually they did not have to inform us because our staff take all these measurements on our regular rounds.
>
> When the interim valuation came, it was prepared as if the work went as per specification – 600mm trench, supplied sand cover and so on. Together with the consultant we disputed this.
>
> I was dissatisfied because we were not informed before backfilling the trench and the contractor tried to use the situation to claim for more than what was actually done.

Parties to the above critical incident pursued their own agendas. The agreement among the parties to the issue in question (along the vertical axis) could be considered as very low, i.e. ‘Level 1’. The degree of certainty of the outcomes (along the horizontal axis) was assessed as ‘Level 3’ because all were trying to follow some specifications, norms and bills of quantities.

Example 4

> Critical Incident No. 0021
>
> Responding stakeholder: Site Engineer

> In this [building] site we have a chaotic situation. The electrical subcontractor was to lay the conduits. It had been sub-sublet and we had lots of problems. Initially, the material did not come on time, enough men were not brought in … We had to bring in their senior personnel and make a lot of fuss to get them moving. Still there was a lot of shoddy work and abortive work. Now, this affected many trades starting from concreting, masonry to finishes … I can say everybody was delayed. The Project Manager should have called everyone and said, 'OK we now have a problem lets see the schedule', try to readjust, refocus where we need to focus, get everyone to say how they will adjust their schedule and then check where they clash and readjust and say, 'Well, yeah we are stuck and this is the problem this is where we are going'. Instead he just kept on asking the people 'When can we finish this? – When can we finish that?' Now, the whole site does not have a focus, you do not know where you are going and many of us lost interest. Now this fellow wants to do this [work], that fellow wants to do that [work] and when they clash both argue that they are delayed and cannot wait for the other's work. So, I will put the problem to the Project Manager. He takes instant decisions to let one fellow override the other. That made many of them angry.
>
> The site is moving at a much slower rate than compared to good support from higher management plus a lot of people are frustrated though staying on this site, I want to request to be transferred out.

The above critical incident was considered as a good example where both the agreement among the parties to the issue in question (along the vertical axis) and the degree of certainty of the outcomes (along the horizontal axis) are at their lowest, i.e. 'Level 1'. As admitted by the respondent, a chaotic situation prevails!

RESULTS

Eighty-two critical incidents collected were mapped on the Stacey Diagram as shown in Figure 3. In addition to the number of incidents that mapped into each square, the diagram presents the number of positive incidents among them. (An incident is called *critical* 'if it makes a "significant" contribution, either positively or negatively, to the general aim of the activity' (Stauss 1993). All incidents, hence, were either positive or negative).

It is apparent that none of them mapped on the squares (1,3), (1,4), (4,1), (4,2) and (4,3) (determined by 1–4 scales along the two axes), indicating a possibility that there are not many instances pertaining to the construction coordination function where it is either 'low in certainty while high in agreement' or 'high in certainty while low in agreement'. A very high number of incidents (73.17%) mapped on the column where the 'degree of certainty' was Level 3, suggesting that it is an area of where much of the coordination activities take place. Therein, 36.59% incidents (70% of them negative) mapped on the square (3,2) (corresponding to Level 2 in agreement).

It is observable from the results that incidence of negative incidents is low at the bottom of the diagram, where there is high agreement among the parties to an issue in question. Possibly, the way construction projects are managed, practitioners are

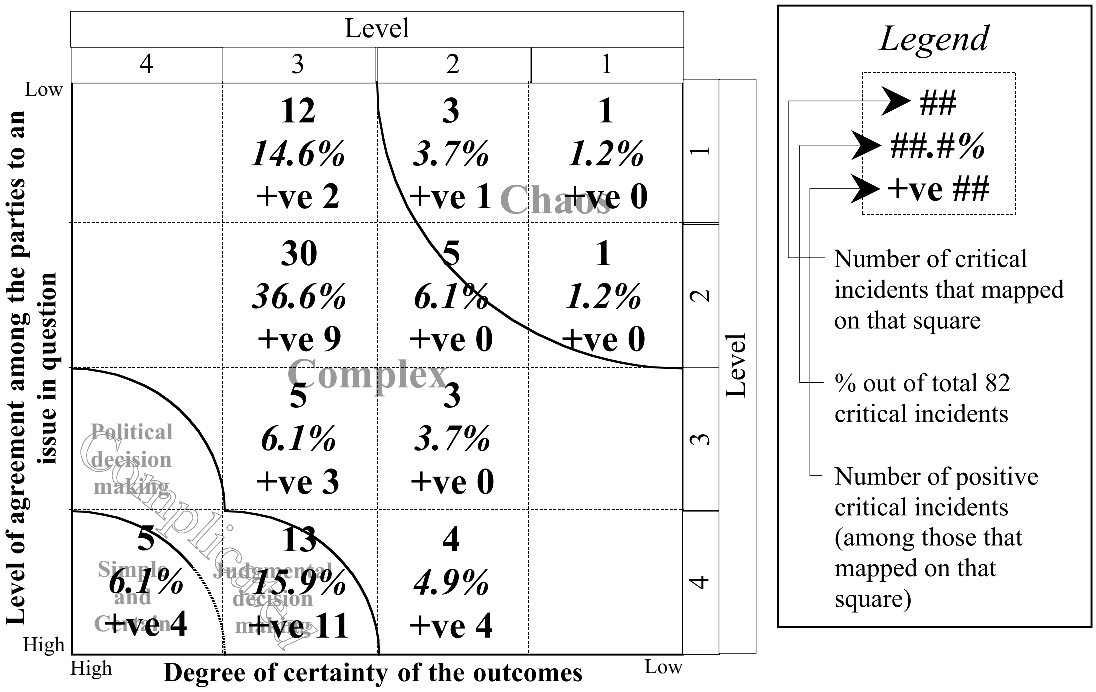


Figure 3: Mapping 82 critical incidents on the Stacey Diagram

better prepared to make judgmental decisions required in these situations. Conversely there is much greater incidence of negative incidents at the top of the diagram, where there is low agreement among the parties to an issue in question. This may be an indication that construction practitioners are less equipped to handle matters of organizational dynamics required either to align the parties concerned or to arrive at a compromise.

The two incidents that mapped into the square (1,1) and (1,2) were rather extreme situations where the project managers were very poor at bringing project teams together and focusing their efforts.

The positive incident that mapped on the square (2,1) was due to a very good policy decision by one contracting company, which enabled excellent grasp of the project requirements by the construction team as follows (stated by an architect):

> Contractors have a QS team for tendering. They are not technical people. Once the tender is awarded, construction personnel complain of various buildability problems; especially, the foremen and the technical staff keep coming to me. One contractor employs the prospective project manager to do the bidding. The project manager and senior personnel at the site, as a result, had a good grasp of the project and the design problems.

Twelve incidents that mapped on squares (3,1) and (3,2) were mostly due to some of the parties not aligning with the project objectives and complicating matters that may have been otherwise resolved. The high incidence of such critical incidents, especially negative ones, indicates the necessity for project managers to be equipped with skills in managing organizational dynamics required in such situations. Incidents on the square (3,3) are situations where project managers went a step further to make certain parties (who usually would not work together) to a construction project work together.

A number of incidents in the bottom row of the diagram are positive incidents due to partnering. The few negative incidents are due to oversight by some personnel. Results, hence, indicate that much progress has been made by the construction industry in handling issues in this area of the diagram.

CONCLUSIONS

Construction coordination is a complex function with a very wide scope. Mapping 82 critical incidents of construction coordination on the Stacey Diagram was expected to reveal what areas of operation would pose greatest challenges to construction practitioners, in terms of coordination.

The results indicate that, as shown by the number of incidents that map, there are not many instances pertaining to the construction coordination function where it is either 'low in certainty while high in agreement' or 'high in certainty while low in agreement'. A very high number of incidents mapped on the column where the 'degree of certainty' were at Level 3, suggesting that it is an area where much of coordination activity takes place. Especially, the high number mapped on the square (3,2) (corresponding to Level 3 in certainty and Level 2 in agreement) and the high number of negative incidents therein suggests that it is an area where future improvement effort needs to be focused.

The results indicated that there is a low incidence of negative incidents in the region where the level of agreement among the parties (to an issue in question) is high. The few negative incidents are due to oversight by some project personnel. Results further suggest that present-day construction practitioners are relatively well prepared to handle issues requiring judgmental decision making encountered as one moves to the right along the horizontal axis.

Much greater incidence of negative incidents is observed in the region where there is low agreement among the parties to an issue in question. This maybe an indication that construction practitioners are less equipped to handle matters of organizational dynamics required either to align the parties concerned or to arrive at a compromise. It was observed that partnering made a number of positive critical incidents that mapped in the high agreement area, among parties that would otherwise have had low agreement. It, hence, highlights the value of endeavours such as partnering that would align disparate parties to a construction project. The results, nevertheless, show the need for construction project managers to be better equipped with skills in managing organizational dynamics required either to align the parties concerned or to arrive at a compromise.

ACKNOWLEDGEMENT

The authors wish to express gratitude to the respondents to the surveys, whose kind cooperation, time and effort made this research possible. We also wish to acknowledge the research grants G-YX23 and G-V458, and other facilities provided by The Hong Kong Polytechnic University, and the funding and support by the North Dakota State University.

REFERENCES

Bitner, M J, Booms, B H and Tetreault, M S (1990) The service encounter: diagnosing favourable and unfavourable incidents. *Journal of Marketing*, **54**(1), 71–84.

Campbell, J P, Dunnette, M D and Arvey, R D (1973) The development and evaluation of behaviourally based rating scales. *Journal of Applied Psychology*, **57**(1), 15–22.

Chitkara, K K (1998) *Construction project management: planning, scheduling and controlling*. New Delhi: Tata McGraw Hill Publishing Company Limited.

Crichton, C (1966) *Interdependence and uncertainty – a study of the building industry*. London: Tavistock Publications Ltd.

De Saram, D D (2002) *Measuring the quality of contractors' coordination activities during the construction process*, PhD Thesis, The Hong Kong Polytechnic University.

De Saram, D D, Ahmed, S M and Anson, M (2004) Suitability of the critical incident technique (CIT) to measure the quality of construction coordination. *ASCE Journal of Management in Engineering*, **20**(3), 97–109.

Fineman, S and Payne, R (1973) Behavioural side of management by objectives: a measurement problem. *Industrial Relations Journal*, **4**(1), 43–9.

Hamlin, B and Reidy, M (1997) Effecting change in management culture. *Strategic Change*, **6**, 435–50.

Latham, G P and Wexley, K N (1977) Behavioural observation scales for performance appraisal purposes. *Personnel Psychology*, **30**(2), 255–68.

Martin, C C (1976) *Project management – how to make it work*. New York: AMACOM.

Schön, D (2002) The crisis of professional knowledge and the pursuit of an epistemology of practice. *In*: J Raven and J Stephenson (Eds.) *Competence in the learning society*. New York: Peter Lang Publishing.

Smith, P C and Kendall, L M (1963) Retranslation of expectations: an approach to the construction of unambiguous anchors for rating scales. *Journal of Applied Psychology*, **47**(2), 149–55.

Stauss, B (1993) Using the critical incident technique in measuring and managing service quality. *In*: E E Scheuing and W F Christopher (Eds.) *The service quality handbook* New York: American Management Association.

Tenner, A R and DeToro, I J (1992) *Total quality management – three steps to continuous improvement*. Reading, MA: Addison-Wesley Publishing Company.

Walker, A (1996) *Project management in construction*. 3ed. Oxford: Blackwell Science Ltd.

Zimmerman, B (2001) *Insights from complexity science for health care leaders*. 2ed. Irving, TX: VHA Inc.

PROJECT MANAGEMENT – LEARNING FROM BEST PRACTICE

Thorbjørn Ingvaldsen[1] and Dag Fjeld Edvardsen

SINTEF Byggforsk (Norwegian building research institute), PO Box 123, 0314 Oslo, Norway

A research project (2002–2006) has developed a method for measuring efficiency in the construction industry. This method has been applied on a sample of blocks of flats projects. The objective is to establish a solid basis for systematic improvements in construction companies. The approach includes use of custom-made computer programs for statistical analysis. The efficiency scores of 122 building projects have been measured using Data Envelopment Analysis. A total of 407 hypotheses of efficiency were established, mainly related to environmental conditions and managerial factors. The hypotheses were tested against the efficiency scores. Fourteen variables were found to have empirical relevance for efficiency. A report generator for two types of individual reports has been created. The first type gives feedback to each project manager regarding the performance of his project compared to Best Practice. This makes it possible for the project manager and his team to reflect on whether their way of managing projects is optimal. The other individual report is for line managers in companies having more than one project in the sample. Key Performance Indicators for the company are compared with those for the whole sample. This enables the line manager to evaluate the performance of the portfolio of projects – and the competitiveness of the unit/company. The intention is to stimulate experience based learning processes. Hopefully, improved productivity will follow.

Keywords: benchmarking, best practice, key performance indicators, experience-based learning, productivity, DEA.

INTRODUCTION

“Learning from Best Practice” has been an expression in almost every industrial sector in the last two-three decades. It reflects the philosophy of the ISO 9000 group of international standards of quality, where systematic, well-organized and well-facilitated processes based on facts are presented as a general recipe for success.

Increased computer capacity during the last decades, and developments in measurement theory have made formal analysis of complex systems possible. A large number of research papers about benchmarking and identification of best practice based on Data Envelopment Analysis (DEA) have been published (Tavares 2002). To the best of our knowledge, information about benchmarking between competing companies in the construction sector is not found in the literature.

In 2001, the Norwegian research council, in cooperation with the construction industry in Norway, declared ambitions to develop a “productivity measurement tools” with the purpose of Best Practice identification in construction industry.

Norwegian building research institute (now: SINTEF Byggforsk) was asked to cooperate with the DEA-skilled econometricians at the University of Oslo/Frisch

[1] thorbjorn.ingvaldsen@sintef.no

Centre in order to create the desired computer-based method for increasing the understanding of productivity in the construction industry.

THE PRODUCTIVITY RESEARCH PROJECT

The development of the method is reported elsewhere (Ingvaldsen and Edvardsen 2007). In this paper, the experience-based learning for performance improvement is in focus, based on the results from the analysis. Basic elements in the research project have been:

- Pilot study of building projects.
- Focus on on-site activities
- The project account books of the general contractors are the main sources for the information of usage of recourses.
- Blocks of flats as units in the sample.
- DEA for benchmarking of the projects’ performance.
- Multivariate regression analysis to identify Best Practice.

The research project and succeeding activities is illustrated in Figure 1. This paper addresses the main activity shown as the shaded box (no. 5), i.e. the development, content and dissemination of personal reports to each of the managers of the 122 contributing projects, as well as to the company managers behind them.

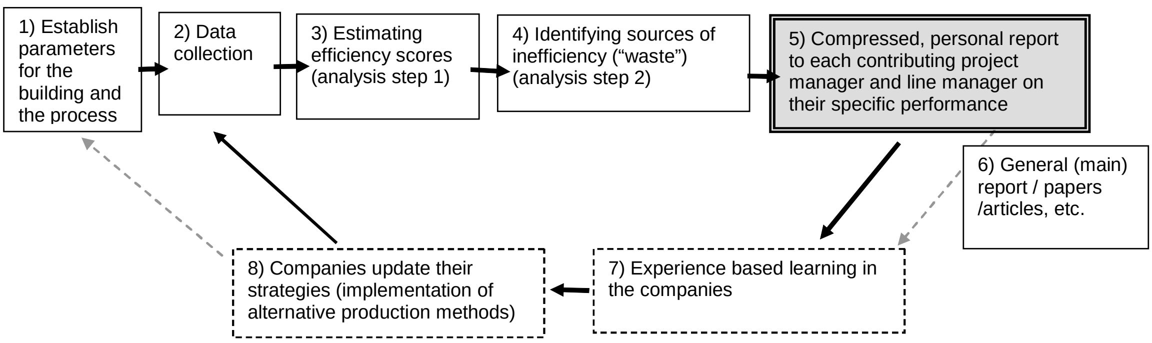


Figure 1: The main parts of the productivity research project (1–6) and expected activities in the industry (7–8)

INDIVIDUAL AND PERSONAL REPORTS

Research project reports are not what the typical construction industry representative prefers as basis for learning activities. With this in mind, the research project decided to provide each contributing project manager, as well as the line manager behind them, with substantial information on their performance compared to “best-of-breed”. The document should be compact, easily read, and include all relevant facts. A report generator was developed to create individual and personal reports of two types:

- The first type has each of the project managers as exclusive receivers. It is a document of only eight pages, containing specific information about the project benchmarked against Best Practice. The most important information is the efficiency diagram for the sample and the efficiency score (E-score) for the project in question. In addition, traditional Key Performance Indicators (partial ratios) for the project, with the sample average as benchmark, are included. The intention is to make it possible for the project manager and his team to reflect on whether their way of managing the project was optimal.

- The second type of individual reports is submitted to each line manager in the 56 profit units connected to the investigation. It includes aggregated information about all projects from his area of responsibility (company, division or sub-division) benchmarked against Best Practice. The purpose is to create a solid basis for the learning process – in order to strengthen the company's competitive edge.

The report to the line managers has the same structure as the project manager version. The content is of the same type, though with aggregated information. The idea has been to focus on performance within the receiver's area of responsibility, and to increase the awareness of improvement activities as an important part of the leadership.

The short, individual reports have three main sections:

- Traditional performance indicators
- The efficiency score
- Information on Best Practice management

Benchmarking is the core element in all three sections of the individual reports.

The remaining part of this paper is structured in the same way. In the following three main chapters the content of the individual reports are presented with particular attention to the experience based learning aspect.

TRADITIONAL PERFORMANCE INDICATORS

Despite the fact that a new and more accurate performance indicator has been introduced (the E-score, see below), the industry will still need its traditional performance indicators. The partial ratios will continue to be useful, both for the day-to-day evaluations and for the experience based learning processes. However, we expect that the new E-score indicator and the Best Practice information from now on will make valuable supplements.

The basic purpose of the data collection was the DEA modelling and the multivariate analysis for identification of Best Practice. As a bonus, the data can be used in forming traditional (partial) performance indicators. As this is where the industry's representatives "feel at home", the individual report template has been organized with one complete page (table) of traditional performance indicators in the first part of the document. The idea is to give the receivers information they easily can relate to, and by this prepare them gently for the parts with the new type of information.

The tables below with examples on performing indicators are extracted from one specific individual report. To ease the reading of this paper a certain unit from the sample has been named "P1" and will serve as our example throughout the paper.

Table 1: Main cost indicators

Indicators (Euros per gross area; equalized to January 2005 by national building cost index)	**Min/max values of 122 units**	**Average of the 122 units (Av)**	**Project P1**	**Ratio Av/P1**
General costs	14/332	151	270	1.78
Construction works	430/1295	705	795	1.13
Technical installations	30/443	178	155	0.87
TOTAL PRODUCTION COSTS	663/1961	1034	1220	1.18

The variation between the lowest and the highest value for all of the indicators is much wider than one would expect for a group of seemingly similar building projects. The total production cost ranges from 663 euros/m² to 1961 euros/m². This means that the most expensive project has a square metre cost that is three times higher than the lowest!

Some frequent comments to differences in building costs are “different standard”, “different area effectiveness”, “the topography and ground conditions”, “degree of off site production” etc. Most of these factors are present in the tables below, i.e. as traditional indicators. However, for humans it is difficult (impossible) to separate the good performance from the less good by simultaneous evaluation of these parameters (as demonstrated by the comments in connection to the tables in this chapter). However, computer software has been developed to make simultaneous evaluation of performance indicators possible – and thus made our multivariate analysis of productivity possible, as shown in the next two main chapters.

Table 1 shows that P1 is not among the best performers (18% above the average for total cost). Looking closer at the figures in Table 1, it seems that the reason is the very high general cost (78% above average). However, since all components in the total building cost affect each other through accounting practices, this understanding may be wrong. The general cost (and also the two other main costs) is decomposed into seven sub accounts (not shown in Table 1). One might expect that the more detailed information would reveal the secret of the very high general cost, but the more detailed figures for the sample shows even wider ranges.

Table 2: Some cost-related performance indicators

Indicators	**Min/max values of 122 units**	**Average of the 122 units (Av)**	**Project P1**	**Ratio Av/P1**
Average salary for main contractor’s working force (euros per hour)	25/54	36	35	0.96
Working hours per produced m² gross area	0.0/9.5	4.2	n.a.	n.a.
Cost subcontractors for construction vs. total production cost	0.0/0.84	0.39	0.27	0.69

What is Table 2 telling about the unit P1? The project pays an average salary rate. This is interesting with respect to the difference in total cost pr square metre, but the information gives us no deeper insight, especially as information in the next cells are lacking (n.a.).

P1 has a lower degree of subcontracting than the sample average. This raises the question about the effect of subcontractors on productivity. The fluctuation in the sample is from 0 (all works done by own employees) to 0.84 (most of the work done by subcontractors). P1 has a lower share of subcontracting than the average (27% vs.

39%). This might be the reason for the relatively high square metre cost of P1, but the available partial indicators do not provide a basis for further understanding.

Table 3: Some key indicators relating to floor areas

Indicators	Min/max values of 122 units	Average of the 122 units (Av)	Project P1	Ratio Av/P1
Gross area (m²)	783/79390	9455	9280	0.98
Area of flats vs. total area (“area efficiency”)	0.46/0.95	0.66	0.61	0.92
Average area of flats (m²)	25/135	78	103	1.32

Differences in floor areas, and differences in utilization of areas, are by many regarded as a main reason for differences in square metre cost. The gross area of the projects varies widely, and one may wonder if the sample deserves the denomination *homogeneous*. Tests of consistency do not define this wide range as a problem for the statistical analysis. Due to the need of as many units as possible in the sample, the research project decided to include some projects that seemed somewhat atypical.

The P1 numbers seem close to the sample average. This is significant for the gross area as well as for the “area efficiency” (0.61 vs. 0.66). On the other hand, the project contains larger flats than the average (103m² vs. 78m²). This information, and some additional information about area in the individual report (not shown here), may encourage the project manager and his team to continue the search of explanations of the relatively high square metre cost by studying traditional indicators. If they are experienced house builders, their “gut feelings” may reveal some relevant insight. But again it seems obvious that the partial approach is not ideal for understanding differences in cost.

Table 4: Examples of different performance indicators

Indicators	Min/max values of 122 units	Average of the 122 units (Av)	Project P1	Ratio Av/P1
Average standard of the building; scale 1–5	1.7/4.6	3.2	3.5	1.08
Injuries at site per 10,000m²	0.0/17.2	2.4	3,2	1.37
Experienced and estimated remedy cost of building defects during warranty period (five yrs) (% of production cost)	0.0/2.0	0.70	2.00	2.86
Amount of change orders; scale 1–4	1/4	2.61	4.0	1.53
Average ground and foundation complexity; average of six sub-indicators	0/1	0.63	1.0	1.59
Relative amount of off-site production; scale 1–9	0/9	3.6	4.0	1.11
Produced area per calendar day (“production speed”)	2.3/60.6	11.2	19.0	1.70
Sustainability; amount of waste fractioning (%)	0/100	50	60	1.2

Table 4 shows that P1 experienced relatively many injuries (37% above average) and an extremely high amount of building defects (186% above average). Together with a high amount of change orders (53% above average) and complexity in ground (59% above average) one may anticipate that these aspects explain a fair amount of the high total square metre cost of P1 (the multivariate test, see below, shows that the two parameters mentioned first have statistically significant relevance for efficiency).

Much higher “production speed” (70% above the average) and more off-site production (11% above average) may have an opposite (positive) influence on the square metre cost, but this is just a guess. Conclusion: Evaluation of the partial, performance indicators is interesting – and might be useful for people of the trade. But the original question, why does the P1 project have a square metre cost that is 18% above the average, is still not properly answered. However, the discussion itself will generate reflection and, hopefully, increase the understanding of the cost aspect of the building process. The possible gain is most likely strongest for companies with more than one project in the sample. In a well-prepared and stimulating setting, the team members can get real experience based learning, which in turn might improve the efficiency of their future projects.

Nevertheless, it is difficult to establish strict conclusions based on the traditional performance parameters alone. Fortunately, this situation can be improved with the new tool, i.e. the individual reports, the new performance parameter (E-score) and information on Best Practice.

THE EFFICIENCY SCORE

The statistical approach

The model in Figure 2 (black box) explains the principles for establishing a mathematical model for benchmarking with respect to productivity and identification of Best Practice. The initial effort was to establish a relevant set of parameters for the building and the building process, see Figure 1, box 1. Based on this, a questionnaire was produced and distributed to project managers in 56 companies (or profit units in large companies). After consistency control of the received data the research project disposed a sample consisting of 122 blocks of flats projects, with a total production cost of 1.2 billion euros, completed during the years 2001–2005.

The benchmarking of project efficiency, i.e. the ranking of the building projects in accordance with their productivity, is based on the parameters Resources (production cost) and Product (gross area, net area, average standard, numbers of lifts). Compared to the square metre cost we regard the E-score to be a more precise performance indicator due to the more detailed definition of the product.

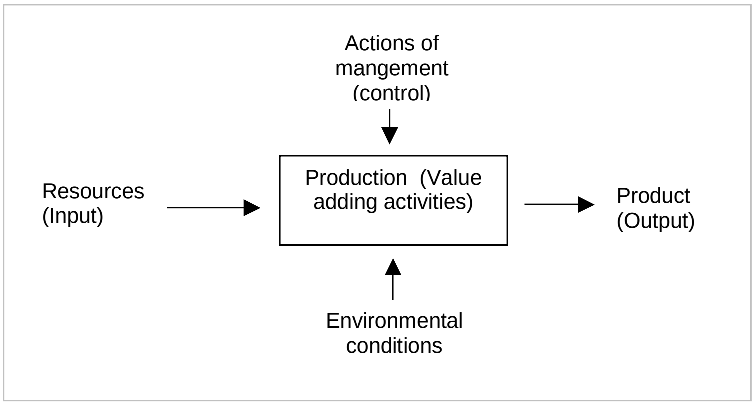


Figure 2: Efficiency analysis – the black box model with four types of variables

Based on the philosophical model in Figure 2, a mathematical model (using the DEA algorithm) was established. The results of the calculations are presented in an efficiency diagram – see further presentation in ‘Benchmarking of efficiency’ below.

The other two groups of factors in Figure 2, i.e. Environmental conditions and Actions of management, contain possible explanations of high, respectively low efficiency. In total 407 parameters (indicators, hypothesis) have been tested against the E-score in multivariate analysis. Fourteen of these were identified as elements in Best Practice, of which three examples are commented in this paper. The model is simple, due to a low amount of units in the sample. Even so, it has an "explanatory power" of approximately 60%, ($R^2 = 0.6002$). See further presentation in main chapter Best Practice – and the learning potential, below.

Benchmarking of efficiency
Based on the philosophical model (Figure 2) and statistical theory, a mathematical DEA model is adapted, through testing of the sample, into a specific model for benchmarking blocks of flats projects. The algorithm returns E-scores for each of the units in the sample and ranks them accordingly (Figure 3). Each bar represents a project and the height of a bar represents the efficiency score (E-score).

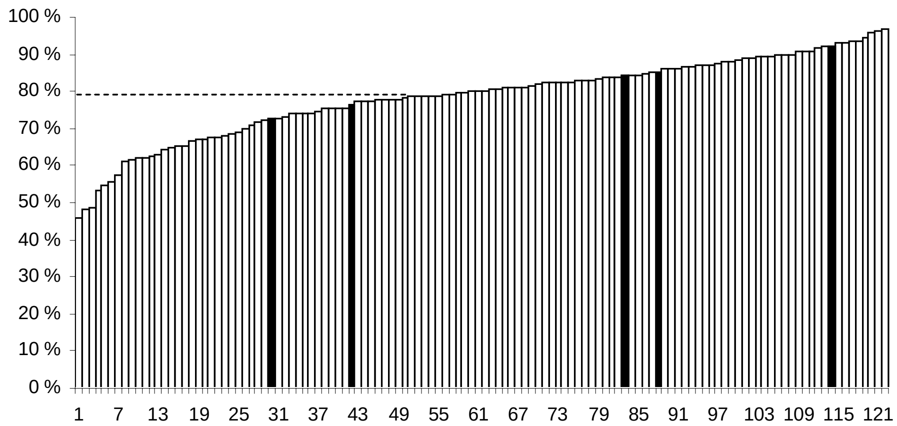


Figure 3: Efficiency diagram

The E-scores range from *c*. 50% to 100%. The Best Practice project is situated to the far right in the diagram. General interpretation: the P1 is represented by the black bar to the far left (which means that it is the least efficient of the P1-owning company's five tested projects). P1 has an E-score of 72%. The distance to full efficiency (Best Practice = 100%) is 28%, which indicates the improvement potential of the project. The *waste* of the project is another way of putting it (Lean Construction thinking, Koskela 2004).

The average E-score for the sample is 79%, indicating that the sample has an improvement potential of 21%. Since the sample represent a total production value of approximately 1.2 billion euros, the improvement potential corresponds approximately to a cost saving of 250 million euros.

Project P1 has a total production cost of *c*. 11.5 million euros. If produced as efficient as Best Practice, the total cost could have been 8.3 million euros, i.e. a cost reduction of *c*. 3.2 million Euros. – The ranking by *efficiency* seems even stricter for P1 than the signal from the *square metre cost* comparison, i.e. 28% vs. 18% improvement potential. Since the E-score is related to the sample frontier and the square metre cost is related to the average of the sample, the 2% numerical values should not be directly compared. The important thing is that the E-score for the highest performing project is approximately twice the value of the lowest (100% vs. 50%), while the worst performing project had three times as high square metre cost than the best one. Conclusion: A better benchmarking method, where a more precise product specification is one important part, reduces the spread of the performance indicator values for the sample with one third.

"The P1 company" is represented by five projects in the analysis (black bars, P1 to the far left). The average efficiency score of the company is 82%. This is above the sample average (79%), which makes it a positive message to the line manager. However, the strongest message from the efficiency diagram is that the performance of this company is rather inconsistent. The large differences in the E-scores of the five projects might depend on circumstances, of which some relate to environmental conditions, but it can also be an indication of weaknesses in the company's management system – or uneven capability/capacity of the project managers and their organizations.

Disregarding the circumstances, the cost-efficiency ranking model (DEA model) gives the P1 team a clear message: "Your performance is far from optimal. Together with your line management, representatives of the four other teams, other colleagues with knowledge on the subject - and a skilled facilitator - you should try to find improvements in the company's procedures and your own way of managing building projects. The Best Practice of the test sample may be a suitable guideline, but don't forget to compare facts about your own project with that of the four other tested ones – and information (facts) from other projects recently carried out by your company."

BEST PRACTICE – AND THE LEARNING POTENTIAL

What are the characteristics of the projects with highest E-score, i.e. the Best Practice projects? Through a multivariate regression analysis of 407 variables (hypothesis), 14 of them were found to have statistically significant relevance for efficiency (in addition, 47 parameters were "close to statistical significance" – i.e. slightly outside the 95% confidence interval. A more detailed model, made available by a new sample of blocks of flats, might deliver a more complete and precise explanation of the large variations in efficiency).

The 14 parameters correlating with the E-scores are of two main types (Figure 2):

- Six are environmental parameters, representing operational limitations for the projects. The typical Best Practice project has not experienced such limitations. Compared to this one the projects with lower E-scores might have one to six operational hindrances of this kind. Some of the hindrances are external (for instance, the weather conditions), and some are internal, meaning that the company's line management have defined the rules (for instance salary conditions).
- Eight of the findings are parameters relating to managerial aspects. This is in line with the main hypothesis of the research project: Productivity depends mainly on how the project manager acts. The findings can be divided into two groups:
    - Three are expressing *consequences* of project management (number of injuries at site, see Table 4).
    - Five are related to the project manager's prioritizing of time, attention and/or prestige.

In the individual reports, the findings are presented and commented in a structured way with the intention to feed any ongoing or upcoming, organizational learning processes in the companies. In each of the three subchapters below, one example from each type is discussed. The complete research work will be presented as a separate article.

1 Environmental conditions

The environmental conditions of a project can make hindrances for the project organization to perform in an optimal manner. The weather has been mentioned as one factor. Another is the contract, in which specific procedures concerning sustainability may be required.

The research project revealed six environmental constraints to the project organization that correlate significantly with cost-efficiency. A company can avoid or reduce the negative effect of such constraints to its projects in three ways:

- Compensate the higher cost with a higher price.
- Reduce cost by change in company policy (e.g. the purchasing policy).
- Carry out more profound changes (reorganization etc.).

Table 5: Example of report to the line manager of P1 regarding environmental constraints of the projects

The BEST PRACTICE projects in the sample are "blessed" by NOT having the limitations listed below	**YOUR COMPANY: Numbers of projects with limits like, respectively unlike the Best Practice**	
	Unlike Best Practice	**In line with Best Practice**
1) Very narrow site area	3	2

Note: The original table contains six rows, one for each of the findings

Table 5 shows that the line manger in the "P1 company" receives an individual report with information saying that three of his five projects have operated on a very narrow site (unlike the situation for the typical Best Practice project). The test revealed that these three projects had an operational handicap. Consequently, they are ranked too low in the benchmarking (too far to the left in the efficiency diagram) and a correction of the E-score is needed: A numerical correction factor is presented, which can be visualized as a short piece of bar on the top of his own bar in Figure 3. The intention is to give fair treatment to the projects that have been handicapped due to circumstances of which they have no influence. This is important with respect to the learning process where the P1 team and the four colleague teams instinctively will pay attention to the internal ranking. Hopefully, the facilitator will succeed in refocusing their attention towards the real issues:

- How can the company reduce the negative effects of very narrow sites?
- What are the *real explanations* of this finding? (Why does a *very narrow site* cause lower cost efficiency?)
- What can be done to avoid increased cost due to a very narrow site?

This rough sketch of the experience learning process may indicate a simple and easy operation. This is not the case. This type of learning processes are in general challenging for all persons involved – in the short as well as in the long term. However, we believe that individual reports based on statistically supported facts will give a far better fundament for such processes than individually interpreted, personal experiences alone can do.

The borderlines between the options in the questionnaire are defined by semantics and not by mathematics. This may cause some confusion. A process facilitator can benefit by the confusion and turn it into fruitful reflection in the working group. Better understanding of the real causes to low productivity on very narrow sites – or high productivity where the site is not very narrow, may be the contribution to the improvement process. Additional information about all the five building projects from the same firm (and possible information from other similar project carried out by the company in recent period of time) will give the participants more reliable information than what is usual in this type of discussions. During such a process, the exchange of experiences and ideas can merge into common insight. Based on this the participants might create an action plan for in situ testing of new approaches to the production of buildings on very narrow sites.

The final documentation from the research project (main report, see Figure 1, item 6) contains additional comments to each of the findings, based on follow-up tests (“nosing around” each of the findings). This type of information, even of limited statistical value, might give suitable support to the collective learning process (“is it possible that the higher cost of very narrow sites is caused by ….?”, etc.).

2a Consequences of project management

Injuries on site can be regarded as part of the product delivered by the contractor (Figure 2). We realize that the ideal efficiency benchmarking model should contain all types of deliveries of the building process, even injuries, building defects, time consume, conflicts etc. However, it has been too challenging for the research project to try this approach in the pilot. Therefore, these types of aspects are defined as *consequences of project management* and treated as a special group of explanatory parameters. Three of those have tested positively with respect to efficiency. One of these is the indicator “Number of injuries on site per Gross area”:

Table 6: Abstract from the individual report to the line manager of “the P1 company”. Topic: Consequences of project management

The BEST PRACTICE projects in the sample are (well) managed and have got results as listed below	YOUR COMPANY: Numbers of projects with limits like, respectively unlike, the Best Practice	
	Unlike Best Practice	In line with Best Practice
1) Low number of injuries per Gross area	2	3

Note: The original table contains three rows, one for each of the findings

Two of the five projects in the “P1 company” have a result regarding injuries unlike (worse than) the typical Best Practice project. The deviation is statistically significant and affects the efficiency score in a downward direction. The numeric value of the correction (%) is known, and should be used to adjust the E-score downwards for the two projects in question. Nevertheless, in the improvement perspective the discussion in the collective learning setting is even more important:

- “Why do three of our five projects succeed in keeping the injuries at a Best Practice level?”
- “How can we get all future projects to perform like Best Practice in this respect?”
- “What do the two, not successful projects with respect to injuries have in common?”
- “Do we know, from earlier block of flats production, or other types of building production, anything particular about rate of injuries?”, etc.

The process facilitator should put effort in the preparation of questions with high potential of reflection, hopefully with common understanding and specific improvement initiatives as a result.

Finally, the finding in itself should be emphasized: Avoiding injuries at the site should have the highest attention, regardless of the economic aspects. Nevertheless, the fact that the productivity is found to be higher when the number of injuries per Gross area is very low, will presumably increase the company and site management's attention to security.

2b Project manager's priorities regarding time and attention

The general hypothesis of the research project was that the productivity in building projects is strongly affected by the quality of the project managers. In the research project the quality of project managers is measured as the relative amount of time spent on 62 different specifications of managerial activities/attentions. The testing gave as result that five parameters relating to managerial aspects had empirical relevance for efficiency.

Table 7: Abstract from the individual report to the line manager in the "P1 company". Topic: Priorities of the project manager

The BEST PRACTICE projects in the sample are managed by PMs that express themselves as listed below	**YOUR COMPANY: Numbers of projects with PM priorities like, respectively unlike, the Best Practice projects**	
	Unlike Best Practice	**In line with Best Practice**
1) Compared to all other activities, I spent much of my time on following up the economy of the project	2	2

Note: The original table contains five rows, one for each of the findings

Table 7 shows how the five project managers in the "P1 company" prioritize with respect to economic aspect of the project. Two of the five project managers act according to Best Practice and two opposite to this (one gave a neutral answer to the question. To keep the table as simple as possible, this is not included).

The table reveals the potential for learning on this subject. How can this be transformed into real understanding and modified behaviour? The answer is collective learning *processes*: To succeed in having project managers to adjust their own prioritizing (behaviour), it is necessary to have them *recognize* that this can improve the productivity of the next projects they are going to manage. A well-facilitated discussion, discretely focusing the difference between the two successful projects and the other two, might lead to the wanted change. Many aspects can explain the "wrong" choices (for instance too high interest in the technical aspects of the project, inadequate delegation within the team, lack of personal competence in economic, etc). The challenge for the line manager and his subordinates is to identify what is needed to modify individual behaviour, and to plan and follow up decided, individual improvement activities. In contrast to the discussion about environmental limitations, the managerial aspect is a much more delicate issue – for all parties involved. The focus on the project manager's priorities can easily turn into a discussion of his personality, which again can affect feelings and cause conflicts. This part of the process should therefore be carefully prepared and conducted by wisdom.

The new situation is that the organizational learning processes can be based on statistical facts. If the process facilitator and line manager succeed in keeping all attention to the facts, i.e. avoiding all kinds of speculation, the benefit of the session should be substantial.

CONCLUSION

A solid foundation for experience-based learning has been established. This has been achieved through a statistical analysis of the efficiency in building projects, and individual reports to the contributing projects and companies. Each of the individual reports contains information custom made for the recipient. This provides of a new way of conducting experience based learning processes in companies.

REFERENCES

Coelli, T J, Prasada Rao, D S and Battese, G (1998) *An introduction to efficiency and productivity analysis*. Boston: Kluwer Academic Publishers.

Edvardsen, D F (2004) *Four essays on the measurement of productive efficiency*, PhD Thesis, Department of Economics, School of Economics and Commercial Law, Gothenburg University.

Ingvaldsen, T and Edvardsen, D F (2007) Effektivitetsanalyse av bygge- og anleggsprosjekter (English: Efficiency analysis of construction projects). Norwegian Building Research Institute (in publication).

Koskela, L (2004) Moving on – beyond Lean thinking. *Lean Construction Journal*, **1**(1).

Tavares, G (2002) A bibliography of Data Envelopment Analysis (1978–2001), RUTCOR, Rutgers University, New Jersey.

ANALYTICAL DESCRIPTION OF THE USES OF REAL OPTIONS IN CONCESSION/BOT PROJECTS

Takayuki Minato[1] and Santi Charoenpornpattana[2]

[1]*Department of International Studies, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan*
[2] *Department of Civil Engineering, King Mongkut's University of Technology Thonburi, 126 Pracha-uthit road, Bangmod, Thung Kharu, Bangkok, 10140, Thailand*

The authors take value creation as an objective in concession investments, and then focus on application of real options as realistic managerial devices to respond to uncertainty. The paper offers a framework for considering concession/BOT related real options into categories, rather than reporting on actual cases of application of a real options approach. The contents consist of roughly into four parts. The introduction explains the view that expected NPV is unrealistic when used in infrastructure projects since they include contingent decisions in the future. The next three sections consist of analysis and description of the uses of real options in concessions. Here, the real options are categorized into three types: *investment*, *contractual*, and *operating options*. First, the notion of irreversibility is introduced into the public sector's valuation of concession projects. The discussion extends to using concession/BOT strategically when infrastructure construction is carried out as a series of interrelated projects. The Tokyo Bay Aqualine example is also introduced as a form of "internal purchasing investments." Next, government support schemes are analysed as forms of real contractual options. It is shown that the options change the risk profile of projects, and become particularly of value for both government and private sectors to cooperate toward their mutual interests. There is also brief reference to prepayment and rescheduling briefly as a form of operating options.

Keywords: contract strategy, government-industry partnership, private finance, real option.

INTRODUCTION

Construction requires making decisions fraught with uncertainty associated with various kinds and amount of risks associated with right-of-way acquisition, accidents, design changes, delays, cost overruns, compliances, etc. In particular, concession projects may fail due to insufficient cash flow that arises from low demand, currency fluctuations and even political risks such as termination of concession, breach of concession contract, high tax enforcement, and so on.

As a practical matter, traditional NPV method does not provide strategic vision for decision makers in concession projects. Typical problems may include optimism with which cash flow forecasts are manipulated subjectively to unlikely levels or bounded by excessive risk aversion and, therefore, discounted too heavily. Moreover, NPV method depends on an expected scenario and may not properly capture subsequent uncertain opportunities.

[1] minato@k.u-tokyo.ac.jp

Real option approach is the extension of financial options. It can be identified to options on real (non-financial) assets. It counts the value attached to management's flexibility to adapt and revise decisions in response to new information. Such opportunities are termed as "options." In general, while the value of financial options can be quantified and observed as market prices, real options perspectives give a way of aiding strategic decision making, thus providing managers with a wider set of strategic alternatives in real investment. Making decisions that contain uncertainty is hard, but a real option approach can help capture future opportunities on unfolding events.

Real options are not always needed, and traditional NPV works when there are no options or the investment includes little uncertainty. However, when investments are extremely valuable and anticipated uncertainty is enough to induce consideration of contingent decisions, option approach may be important. Large construction projects satisfy such conditions because its investment is complex and time scale is long. The features are further magnified for BOT type projects within which the project company undertakes finance, construction, operation, and maintenance.

In addition, construction projects are irreversible. That is, the investment cannot be recovered once it fails. This arises from a specific feature of construction, that is, low liquidity. Irreversible investments are often managed in a phased approach by delaying them until uncertainty is resolved in the future. Since taxes are the major source of funding for typical public construction, the use of BOT as a government option may sometimes be effective instead of direct investments. In such a circumstance, real option approach becomes of value to avoid sunk costs if used properly.

In the following, brief review of financial options is given first. This provides readers with institutional description of option structure. Then, the applications of real options will be presented in detail. The taxonomy of real options includes *investment options, contractual options*, and *operating options*, (Amram and Kutalilaka 1999). According to the classification, "investment options include decisions about scale (expansion, contraction, or disposal). Timing options that accelerate or delay investment are also categorized in this. Contractual options are specific contract terms that change the risk profile faced by asset owners. Operating options consist of when to switch inputs, when to switch outputs, and when to temporarily shut down the operation." The discussion mainly focuses on irreversible costs in investment, and government support schemes in the form of contractual options.

BRIEF REVIEW OF STOCK OPTIONS

Option trading was initially developed in the financial market. Options markets exist for a wide variety of instruments today. However, it may be still necessary to recall the definition of two types of options in finance: a call option and a put option on common stocks. In general, a *call* option is defined to be a contract giving its owner the *right to buy* a fixed number of shares of a specified common stock (underlying asset) at a fixed price (exercise price) at any time on or before given date (expiration date). On the other hand, a *put* option is a contract giving its owner the *right to sell* the shares in the same way (Cox 1985).

The determinants of option value consist of the same set of variables for both calls and puts: (1) current stock price; (2) exercise price; (3) time to expiration; (4) stock volatility; and (5) interest rates. In case of stock option, cash dividends also matter.

There are also other determinants such as expected growth rate of stock price, tax rules, transaction costs, market structure, etc.

There are reasons why investors use options. Options may offer them a wider range of alternatives available for making decisions in investments. They include, for example, a flexible pattern of returns, a favourable opportunity to borrow or lend, tax advantages, lower transaction costs, etc. In essence, options provide a means of hedging against uncertainty in stock volatility.

An option is a right, but not an obligation. It has value because there is uncertainty included in the underlying asset. In the case of stock options, the pay-off function bends at the exercise price (see the left–side diagram of Figure 4 for a call option. The pay-off of a put option is a mirror image of this.). The non-linear function shows how uncertainty creates value. With options, losses are limited to a certain level, and the option may be executed when uncertain moves toward the upside potential.

At this point, it is interesting to understand that NPV valuation is just one kind of option valuation. The decision is made to go for the investment when the sum of present value is larger than initial investment. It is simply the same as option valuation by taking the initial investment as the exercise price; the timing of a decision depends on whether there is uncertainty in the future.

The difference between investment on security and infrastructure includes the feature of risk controllability. In general, the risk of securities is not directly controllable; therefore, investors try to control the allocation of costs on the component securities. On the other hand, the scope of a project is determined according to such conditions as resource availability and necessary job sequences (Minato 1995). This indicates that engineering capacity finds more ways to apply real options in operation.

REFERENCES ON REAL OPTIONS IN CONSTRUCTION

Most of the research literature in construction management and infrastructure planning deals with the concept of investment options. Benaroch (2001) proposed a methodology for planning the creation of operating options designed to maximize the value of an investment in light of the risks underlying that investment. The paper also shows how each type of options can deal with a variety of risks in the project management context.

Jonhstones (2002) shows that government should take into account the value of options, specifically the contracting out option, in outsourcing decisions. The option to contract out provides government with opportunities to hedge against uncertainty in the cost stream. Ho and Lie (2003) proposed an analytical methodology for evaluation of the strategic value of technology investment by the real options approach. This proposed framework specifically considers the technology investment risk and embedded managerial options.

Infrastructure investment creates further investment opportunities, and changes the strategic position of the enterprise. Smit (2003) focuses on the optional and strategic features of infrastructure investment. The paper focuses on, in particular, an analysis of European airport expansion. The result indicates that airports with infrastructures that are less constrained by growth regulations capture more value, because they are in a position to exercise growth options available in the airport industry.

Zhao *et al*. (2004) developed a multistage stochastic model for decision making in highway development, operation, expansion and rehabilitation based on a real options framework. Three uncertainties are taken into account in this model, namely, traffic demand, land price, and highway deterioration and their interdependency. Real options in both development and operation phases of a highway are also incorporated in the model. A valuation model of infrastructure development and expansion is also developed by Zhao and Chung (2006), reflecting the decision maker's risk preference into analysis.

INVESTMENT OPTIONS – THE IRREVERSIBLE INVESTMENT

The notion of irreversibility is not generally considered in decision making when a new project is taken. Irreversibility refers to the loss by giving up the opportunity to change decision in the future. Once resource is committed, it cannot be recovered, reversed or radically changed without "substantial loss". Infrastructure investment is contingent on follow-on investments, and it should be taken into account as sunk cost in the case where future opportunity is sacrificed.

While opportunity cost is normally the sacrifice of equivalent alternatives at the time decision is made, "opportunity cost of irreversibility" is the cost of sacrificing the alternatives over future time and in relation to subsequent projects. By taking into account the cost, it is suggested to defer the investment until the optimal condition is achieved. The "optimal condition" is referred to the conditions that loss due to deferring exceeds opportunity cost of irreversibility (Figure 1).

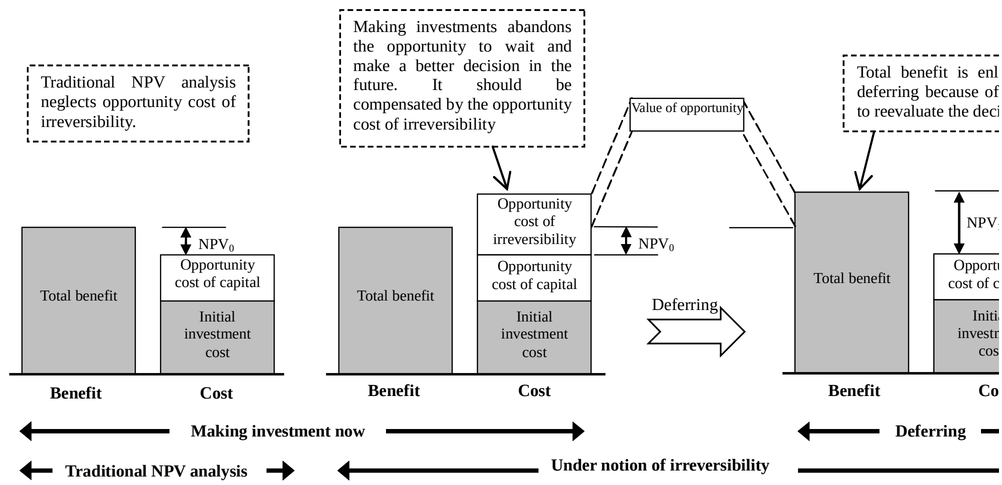


Figure 1: Concept of the "opportunity cost of irreversibility" in investment decision

In the BOT project, the government generally need not commit capital, and thus frees itself from part of the opportunity cost including opportunity cost of irreversibility by transferring this opportunity cost to the project company. This in turn means that the value for the government could be enlarged if BOT is employed instead of using traditional public investment. In effect, the government could preserve the value of opportunity associated with time otherwise sacrificed by committing irreversible cost (Charoenpornpattana 2004). This will be significant potentially if project companies are likely to differ from government in their valuations of the opportunity cost of irreversibility. Such differences may derive from the switch to user-charges as opposed to taxpayer funding and thus a different valuation of benefits, or from different attitudes to uncertainty, or from the effect of government support schemes in which case the opportunity cost is only partially transferred. With no difference in perceived opportunity cost, the project company may also choose to defer decision in all cases where government would choose to defer.

Furthermore, the effect of irreversibility is extended when infrastructure is carried out as a network of interrelated projects. Taking into account the effect of irreversibility, the government will defer public investment until the time when project A can be optimally invested. The growth opportunities to undertake projects B and C are not provided prior to the point where project A is invested (Figure 2).

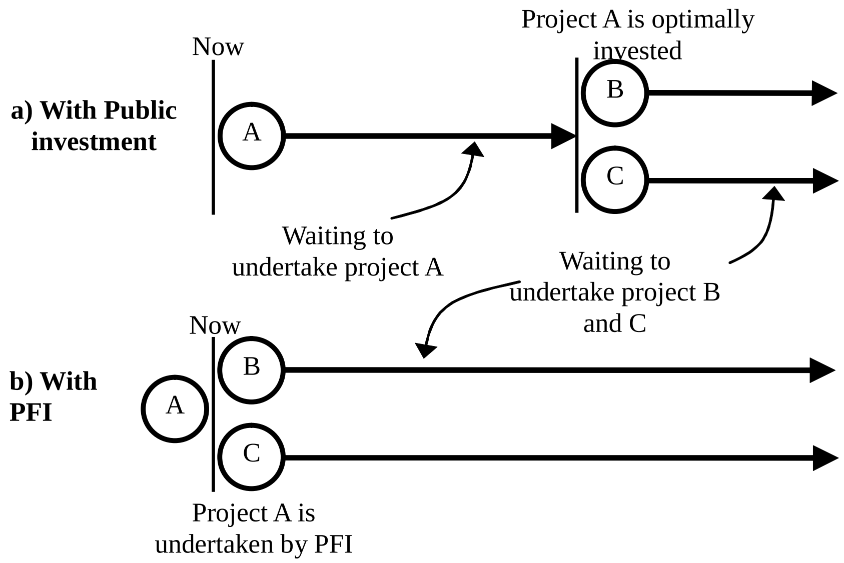


Figure 2: Growth opportunity with (a) public investment and (b) BOT

Suppose now that BOT is available to the government to undertake project A. The government does not need to consider deferring to undertake project A, because it is freed from the effects of irreversibility. In effect, the decision can be made immediately, provided that the project company is committed to invest immediately. As project A is undertaken, growth opportunity for projects B and C are activated. The implication behind this is that the dependencies between interdependent projects are resolved by using BOT, because the dependency condition is fulfilled by having project A commenced. Therefore, it allows the government to acquire growth opportunity to undertake projects B and C.

In conclusion, by public investment, the government faces an investment dilemma between (1) making the investment at the expense of value of opportunity associated with time and (2) postponing the investment at the expense of value of growth opportunity. In contrary, if BOT is employed, the government can be free from the effect of irreversibility, because it incurs no irreversible expenditure. Consequently, the government can immediately obtain the project and preserve the full value of opportunity associated with time, and the value of growth opportunity associated with related projects. Therefore, the option becomes a superior alternative over public investment by this mechanism. Then, the contributions of this research are shown to be that it sheds light on sunk cost, or irreversibility of executing the option from the government side.

INVESTMENT OPTIONS – THE INTERNAL PURCHASING INVESTMENT

An interesting application of real options is found in the Tokyo Bay Crossing Highway, also known as the Aqualine. It took ten years to be completed in 1995 as a major project to cross the Tokyo Bay, linking Kawasaki and Kisarazu. The structure contains both bridge and underground tunnel, and is made of a massive three-chamber single box girder with the web ranging from 3m to 10m in height. Although not by BOT but the “third-sector” scheme, it was initially estimated that the traffic volume for the first 20 years would be 33,000 (vehicle/day), and 64,000 (vehicle/day) thereafter. Unfortunately, however, the actual demand has been about half of the expectation.

Other than its current financial performance, it cannot be denied that the Aqualine includes a unique design option. The highway was put into utilization with four driving lanes, with an option expandable to six lanes in the future. This meant that capacity could be switched for possible traffic change in the future by flexible design, which is in fact a type of investment option. Although the option has not been executed because of the current low demand, it was planned so that internal investment on flexible design could make adjustments to capacity in accordance with actual demand magnitude. According to Marukawa (2003), suppose the structure had been constructed with six lanes then the loss would have been worsened approximately by 30%.

It is typical of planners to justify their “gut feel” in demand estimation before construction. The result is that such decision sometimes loses credibility after all if situation goes wrong. Instead, real options approach can be incorporated to strategically make decisions by incorporating “internal purchasing investments” to respond to operational uncertainty in the future.

The essence of the discussion here includes the question of how to evaluate the value of “design”. In general, design is defined in terms of such engineering criteria as shape, strength, appearance, etc., only. However, the value of infrastructure extends to not only physical functions, but also social capacity related to environment, social justice, culture, etc., over time (Minato 2007). The question is how much you are willing to pay extra costs of having valuable infrastructure for the future.

CONTRACTUAL OPTIONS – THE CONCESSION AGREEMENT

In BOT projects, government financial supports may be integrated in the contract. The private contractors are just interested in having support when they have to bear risk. As discussed in the previous section, for example, if projects are realized earlier under concession/BOT, contractual options may be effectively used together with investment options to provide private sector with “a bundle of options support” for not only the base project, but also follow-on projects.

Supports include, for example, direct investment on equity, subordinated loans, cash subsidies and other development rights such as tax benefits, land lease, extension of concession, etc. These supports sometimes play vital roles for the project company to improve income stream by reducing capital requirement and risk exposures in cash flow during the project. According to Fishbein and Babbar (1996), there are eight specific government financial supports in the case of highway projects. With the supports, the government provides a right to the project company to execute the following alternatives:

- Equity guarantees: a right to sell the project to the government with a guaranteed minimum return on equity.
- Debt guarantees: a cash-flow deficiency guarantee for repayment of debt.
- Exchange rate guarantees: a compensation for increases in local cost due to exchange rate movements.
- Grants and subordinated loans: a repayment of subordinated loan after the senior loan, or non-repaying grants. Subordinated loan will be repaid to government after the senior loan.
- Shadow tolls: a specific annual payment (per vehicle) depending on traffic demand.
- Minimum traffic guarantee (or minimum revenue guarantee): a cash compensation if traffic falls below a specified minimum. On the contrary, there is a case that cash may be reimbursed to the government if the traffic is overloaded beyond a specified ceiling, or maximum revenue ceiling.
- Revenue enhancements: a priority right with regard to limited competition, facilitated demands or development of ancillary facilities.
- Concession extensions: a right to extend the concession term in the case that the revenue falls below a specified target.

Figure 3 shows the impact on the project company's financing ability in association with government financial exposure of individual schemes. Each of the eight instruments has their own characteristics. The primary function of government support is to share some of the risks that are hard to be owned by the private company. This in turn means that government provides options to the private sector for compensating uncertainty.

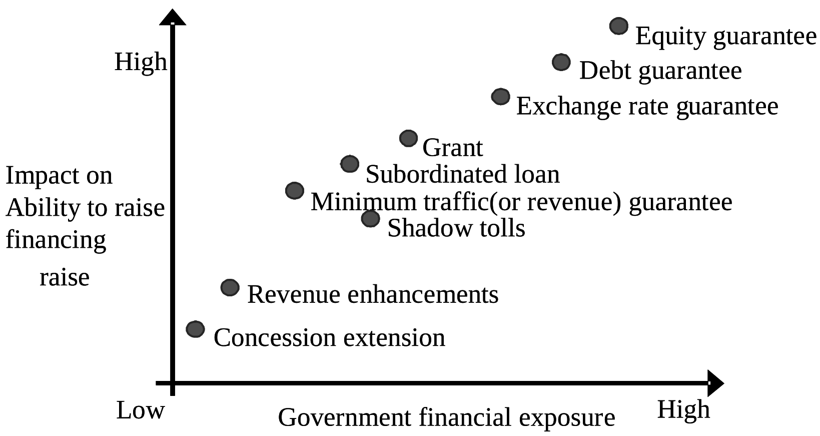
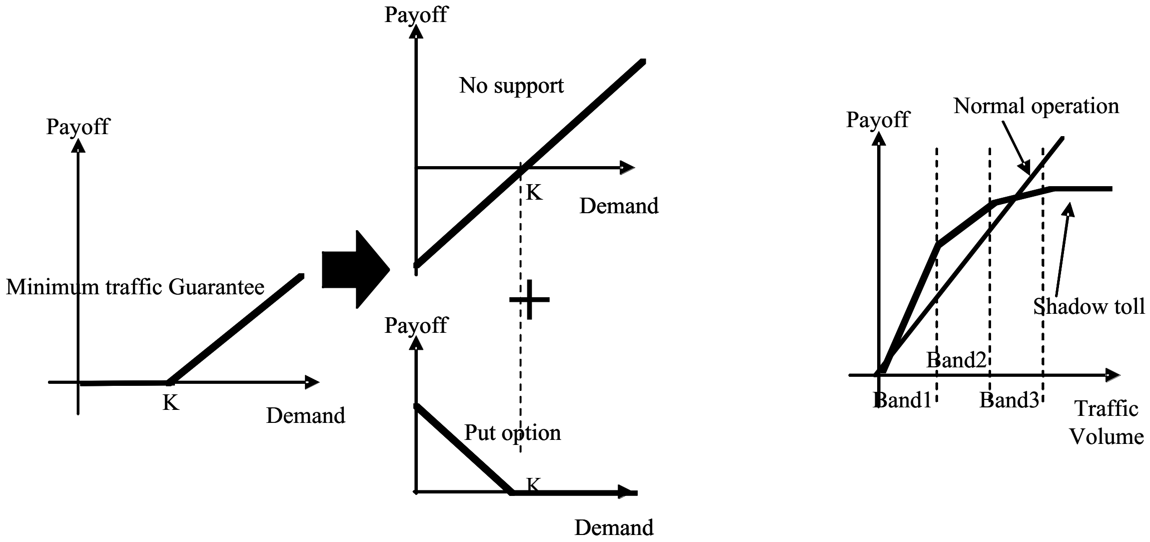


Figure 3: Range of options for government support (Fishbein and Babbar 1996)

Most of these government supports consist of contingent contracts. Minimum traffic (revenue) guarantee, for example, has the feature that the project company holds a call option to hedge downside risk when actual traffic demand goes below a certain level, can be broken into two positions: one with no government support and the other with a put option. Suppose the payoff line for the position with no support is a 45" line with positive slope. If the demand is zero, the position will experience a certain loss. However, minimum revenue guarantee combines a put to cover the loss below K. In other words, minimum revenue guarantee is a type of support that has a form of put given by the government to the project company.



(a) Minimum traffic guarantee (b) Shadow tolls

Figure 4: Payoff diagram of minimum traffic guarantee and shadow tolls

In analysing the put option, the underlying asset is the project's cash flow. A set of other variables is also shown in Table 1.

Table 1: Variables of minimum traffic guarantee support

Variables	**Minimum revenue guarantee**
Underlying asset	Project's cash flow
Exercise price	Cash flow at minimum traffic guarantee
Maturity	One year
Volatility	Volatility of cash flow
Risk-free interest rate	Risk-free interest rate

Shadow tolls have the same feature as the minimum revenue guarantee and its extension. It is a government support scheme that per vehicle payment is given to the project company on the basis of actual usage. The formulation generally divides toll rates (per vehicle) into two to four bands (Figure 4b). The system is put into practice in such a way that government makes more payment per vehicle when the traffic volume is less. The rate per vehicle decreases as the traffic demand increases.

While most support schemes can be generalized in a form of ordinary calls and puts, there are some options that need complex formulation. For example, concession extension belongs to this type. As an example, the M2 toll road in Australia is a BOT project that includes concession extension on the basis of project performance. The initial concession is 36 years; however, it can be extended if internal rate of return (IRR) of the project ends below 16.5% at maturity. In the same way, the concession can be extended up to maximum 45 years depending on the IRR every three years thereafter. This scheme is different from, for example, minimum revenue guarantee, in the following; 1) the option is given at the end of project while minimum guarantee is provided yearly; therefore, 2) the option is *path-dependent*, in which the value of the option depends on the value of NPV in previous years, and 3) payoff does not simply represent increasing function in relation to IRR. It is a so-called compounded option, which is defined to be an option on an option. For detailed formulation and simulations, refer to Nakahama (2003) and Charoenpornpattana *et al*. (2003).

OPERATING OPTIONS – THE FINANCING AGREEMENT

Operating options are sometimes viable between loan providers (banks) and the project company. For example, *prepayment* and *rescheduling* are the ways that investment banks use as a device in managing credit risk. The devices are used to accelerate, stop or extend the payment of debts on the basis of future cash flow. In these schemes, the timing of re-contract becomes crucial; thus, it is important to analyse the value of project cash flow for reduced or extended timescales.

This topic includes interesting development both theoretically and practically. The above example is just one of them, and its description needs more space and careful clarification. For details, refer to Murauchi (2007)

CONCLUSIONS

The usefulness of valuation using real options is presented for concession/BOT projects. It was first argued that NPV evaluation does not give strategic consideration when investments include “attractive” contingent decisions. The traditional NPV method is just a type of real option analysis in which the decision is made to go only when the sum of present value is larger than initial investment.

By categorizing real options into *investment*, *contractual* and *operating,* it was first discussed that irreversibility is most critical in construction since the investment includes opportunity costs as sunk components. Since construction is carried out as a series of successive interrelated projects, using concession/BOT as an investment option gives government more flexibility in allocating total budget, if a project company can be found that takes a different view on the desirability of immediate investment. An example of design option was also introduced as a form of “internal purchasing investments”. The Tokyo Aqualine was shown, in which the structure was designed to “easily” increase capacity for possible up-side increase of demand. Next, it was shown that some government support schemes are formulated into contractual options for asset owners to execute “rights” to protect against liquidation of down-side risks. The contractual options particularly become of value when government and the private sector try to change risk profiles for their mutual interests. For operating options, *prepayment* and *rescheduling* are briefly referred to as a device to accelerate, stop or extend the payment of debts of projects.

REFERENCES

Amram, M and Kulatilaka, N (1999) *Real Options*. Massachusetts: Oxford University Press.

Benaroch, M (2001) Option-Based Management of Technology Investment Risk. *IEEE Transaction on Engineering Management*, **48**(4), 428–44.

Charoenpornpattana, S (2004) *Value of Irreversibility in Private Finance Initiative – Evaluating it by Real Options Approach*, Unpublished PhD Thesis, Department of Civil Engineering, The University of Tokyo.

Charoenpornpattana, S, Minato, T, and Nakahama, S (2003) Government Supports as Bundle of Real Options in Build-Operate-Transfer Highways Projects. *In:* L Trigeorgis (Ed.), *7th Annual International Conference on Real Options*, Washington DC.

Cox, J C and Rubinstein, M (1985) *Options Markets*. Prentice-Hall Inc.

Fishbein, G. and Babbar, S (1996) *Private financing of toll roads*. RMC Discussion Paper Series 117, the World Bank, Washington DC.

Ho, S P and Liu, L Y (2003) How to Evaluate and Invest in Emerging Technologies under Uncertainty. *Journal of Construction Engineering and Management*, **129**(1), 16–24.

Johnstones, D (2002) Public Outsourcing as an Exchange Option. *ABACUS*, **32**(2), 153–76.

Marukawa, H (2003) *On project evaluation considering decision flexibility* (in Japanese), Unpublished Master's Thesis, Department of Civil Engineering, The University of Tokyo.

Minato, T (1995) *A Methodology for Project Risk Control, A Work Package-Based Approach Using Historical Cost Control Data*, Unpublished PhD Thesis, Department of Civil Engineering, University of California at Berkeley.

Minato, T (2007) Considering "Social Adaptation" of Infrastructure and Consequence of its Impact on Sustainability. *In: Proceedings of International Symposium on Dialogue Between Social and Natural Sciences*, 26–8 February 2007, The University of Tokyo. Association of the Integrated Research System for Sustainability Science (IR3S), to be published.

Murauchi, Y (2007) *A Methodology* (in Japanese), Unpublished PhD Thesis, Department of International Studies, Graduate School of Frontier Sciences, The University of Tokyo.

Nakahama, S (2002) *Evaluation of revenue schemes for BOT projects using Real Options Theory and its Allocations* (in Japanese), Unpublished Master's Thesis, Department of Civil Engineering, The University of Tokyo.

Rose, S (1998) Valuation of Interacting real options in a tollroad infrastructure project. *Quarterly Review of Economics and Finance*, **38**, 711–23.

Smit, H (2003) Infrastructure Investment as a Real Options Game: The Case of European Airport Expansion. *Financial Management*, **32**(4).

Zhao, T, Sundararajan, S K and Tseng, C L (2004) Highway Development Decision-Making under Uncertainty: A Real Options Approach. *Journal of Infrastructure System*, **10**(1), 23–32.

Zhao, T and Chung, C F (2006) Infrastructure Development and Expansion under Uncertainty: A Risk-Preference-Based Lattice Approach. *Journal of Construction Engineering and Management*, **132**(6), 620–5.

RISK MANAGEMENT IN PUBLIC–PRIVATE PARTNERSIP (PPP) PROJECTS FROM THE PROJECT MANAGEMENT PERSPECTIVE

Hemanta Doloi[1] and Xiao-Hua Jin

Faculty of Architecture, Building and Planning, University of Melbourne, Victoria 3010, Australia

The research explores the project management issue and its contribution to effective management of risks in public–private partnership (PPP) projects. A framework has been established by identifying the emerging challenges and the approaches to effective risk management. While the approaches to identifying the appropriate partnership arrangement and bidding processes are reasonably established, in general, the effective management process in large-scale transactions involving two different agencies: public and private in PPP projects is quite critical. There has been increasing evidence of criticism in delivering public projects with private participation across Australia as well as many other countries. In order to evaluate the management performance of PPP projects, a thorough analysis of the nuts and bolts of the partnership arrangement is important at an early stage, considering a whole-of-life approach. The literature survey and the case study proved the importance of the management programme for the effective execution of PPPs. Appropriate understanding and quantification of critical risks in PPP projects are the keys for project managers to make the right decisions and take relevant action. A recently completed major infrastructure project in Melbourne has been studied to understand the underlying challenges in managing and delivering PPPs from the project manager's perspective. These challenges include design complexity, stakeholder integration, risk allocations and constructability issues. The framework highlights the project management approach for appropriate identification, allocation and management of risks associated in the PPP process.

Keywords: Australia, project management, public–private partnership, risk management, value management.

INTRODUCTION

Delivering public projects through private sector funding is gaining widespread popularity in many countries including Australia. Over recent years, governments around the world have redefined their role by restructuring, corporatizing or privatizing some areas of government activity that had been deemed core in the past (Arndt 1999). Government is no longer considered the sole provider of public works or services. The concept of providing concessions to financially unattractive projects has enabled governments to maintain a strategic interest in the infrastructure and finally leads to a range of public–private partnership arrangements (Miners *et al.* 1995). Public–private partnership (PPP) has been recognized as one of the major procurement strategies for governments in providing infrastructure systems.

However, the joint ownership of such a procurement strategy is quite complicated, owing to the presence of multiple stakeholders in the PPP process. While state

[1] hdoloi@unimelb.edu.au

governments in Australia have been devising their own solutions to delivering contemporary services to the public through fundamental PPP infrastructure projects, the results from a few completed projects so far have not been absorbed effectively among the end users. As anyone reading the press will have seen that there is still a strong groundswell of dissent over the effectiveness and value of PPPs as a tool to create and manage social infrastructure across the states in Australia (Millar and Moynihan 2006; Tomazin and Myer 2006). While it is becoming evident that there is a significant opportunity for private sectors in building and potentially operating the social infrastructure systems, the question whether the PPPs will be a long-term model remains unresolved. For instance, a recently completed AU$700 million redevelopment of the Southern Cross Railway Station in Melbourne with a complex roof structure resulted in a significant cost overrun. Among other things, design complexity and poor stakeholders' communications are considered to have contributed significantly to such failure. Similarly the AU$800 million Cross City Tunnel project in Sydney CBD failed in securing estimated tariff stability in the PPP arrangement which has opened up a full debate on decision makers and management competencies in the Australian context.

Today's PPPs and project delivery are seen to be a more strategic venture where multi-partner dependencies contribute to the fulfilment of strategic objectives of the entire business systems. In current PPP practices, the challenging complexities of efficient project delivery are typically due to following reasons:

1. presence of uncertainty and risks affecting virtually all aspects of project creation, delivery and operation;
2. complex project composition and associated functional integration;
3. complex network of relationships among the direct and indirect project's stakeholders;
4. multi-project operation, prioritization, investment strategy and delivery decisions in government projects;
5. increased public participation, regulatory obligations and value for end users.

Given the profound changes of project environments and the increasing evidence of the inadequacy of the current project management models, this research aims to address the following questions:

- How does the diversity and complexity of today's projects delivered through the PPP impact on establishing the next generation project management platforms?
- How can the current project management principles be used for strategic delivery of PPP projects?
- Will project management be seen as a core capability in delivering strategic advantage to the PPP projects?
- What will be the value-addition process upstream and how is project organization responsible for delivering value-for-money in PPP projects?

Over the past few years, securing value for money in PPPs have been a major area of investigation across Australia. Challenges faced in risk identification, allocation and management strategy across multifaceted stakeholders in PPPs is currently one of the major areas of research in progress at the University of Melbourne (Doloi and

Raisbeck 2007a, b; Jin and Doloi 2007). While the cynic's criticism of the process and effectiveness of delivering government projects through PPPs becomes a norm across Australian development, the project manager's role and competencies in meeting the project target (in terms of scope management, time and cost control) are easily overlooked. In this paper, the authors aimed to identify some of the project delivery risks encountered over the PPP life cycle from a project manager's perspective. A real life case study has been used to analyse and establish a benchmark of these risk issues in the Australian context. If such risks are clearly understood at the early stage, appropriate management strategy can significantly contribute towards delivering PPPs successfully.

PPP DEVELOPMENT IN AUSTRALIA

There has been considerable activity in Australia with its complex federal system. The Australian government released its private financing policy in 2001 based on three core principles, viz. value for money (VFM), accountability and transparency. Pursuant to these policies, PPPs have been implemented successfully in many jurisdictions and in many industry sectors including transport, health, education, justice, defence, energy and utilities (DFA 2005). The State of Victoria in Australia has been playing a leading role in PPPs' development. The active Partnerships Victoria (DTF 2000) and the volume and sophistication of the PPP projects, such as Southern Cross Railway Station, Melbourne Convention Centre, and EastLink projects, mark Victoria as the leading force in PPP development in Australia. Other States, such as New South Wales and Queensland, are following Victoria closely in terms of developing PPPs (Hayford 2006).

Nonetheless, the PPP model and its widespread criticisms have encompassed cost overruns, delays, design flaws, write-downs, legal disputes and anxiety over service delivery in the longer term (Coulson 2005). Consequently, the issues arising out of economic infrastructure PPPs have led some critics to argue that PPPs have become a mechanism for handing windfall profits to private investment banks while leaving taxpayers to bail out failed projects (Jay 2005). Indeed, as PPP markets have grown across the globe, there has been a corresponding rise in research focused on PPPs (Akintoye and Chinyio 2005; Dixon *et al*. 2005; Li *et al*. 2005). Studies of risk in the PPP context have tended to focus on different segments of the PPP lifecycle and for the most part they have focused on engineering and economic infrastructure rather than social infrastructure (Zhang 2005; Mattar and Cheah 2006).

This paper discusses a link between traditional project management and PPP project management for developing a framework to simulate the factors associated with the risks in PPP social infrastructure projects. The discussion is based on the case study based research in the recently completed Southern Cross Station (SCS), which is a hybrid social and economic infrastructure project in Melbourne, Australia.

SOCIAL VS. ECONOMIC INFRASTRUCTURES

In Australia, like many other countries, infrastructure is usually broken into two broad categories, which are those related to either economic or social services. Johnston *et al*. (1999), for instance, referred to infrastructures as 'the productive capital structures that underpin the economy and society and contribute over time to the achievement of its economic and social goals'. The OECD's (1991) definition of infrastructure has been frequently adopted:

> Infrastructure comprises the capital works required in urban areas for households to have access to major economic and social services. The OECD groups infrastructure into two broad categories. The first is economic infrastructure comprising networked services such as hydraulic facilities, highways and other transport facilities, and energy distribution networks. The second category, social infrastructure comprises a broad range of facilities that provide community services such as education, health and leisure and law and order.

Though conceptually a holistic view should be taken when considering infrastructure, it would be more practical to analyse social and economic infrastructures separately, owing to their inherent distinction (Duffield 2001).

An examination of the structure and related issues is timely because in Australia, PPP markets are becoming more complex as social infrastructure projects are beginning to appear in the market. These projects may include courts, hospitals, prisons and even schools and perhaps even social housing (see the National PPP Forum, at http://www.pppforum.gov.au/nationa-l_pipeline). These projects often begin with a decision within the public sector that a particular project is needed and then that the project is best financed or procured using private sector finance. Once this financing decision is made, it is naive to assume that risks are entirely allocated across from the public to the private sector. However, potential project risks and allocations between various parties depend on the financial and legal project development environments.

The emergence and presentation of risks in social infrastructure projects may not often reflect the strict partitions within the PPP environment. The risks inherent in social infrastructure PPPs are arguably more complex to manage and foresee because they require intensive architectural and urban design along with a higher degree of user consultation. Social infrastructure PPPs are often situated within a complex political context. Moreover in social infrastructure projects the PPP life cycle encompasses the entire range of building procurement and also includes the complex service agreements which are used to operate the facility after it is constructed. This situation has led to questions on the role of the project managers beyond delivery (Brady *et al*. 2005; Leiringer and Green 2005). Given that concession periods of PPP projects often extend out to 25 or 30 years, it is important for public sector promoters to understand how to foresee and manage the risks that may impact upon them, beyond delivery and into the operational period.

INVESTIGATION APPROACH

Before setting the benchmark on the risk management framework, a number of interviews and an industry workshop (total 65 participants) were conducted to seek opinions from the industry about risk management practices and allocations strategies in PPP projects. This pilot study was funded through a grant from the University of Melbourne. Most of the interviewees are senior project managers and project directors from government as well as private firms involved in PPP projects. The initial discussion was steered using a set of structured questions related to risks associated in PPP projects across the board. By adopting a detailed, project-specific questionnaire, the interviewees were then asked to identify the risks in the projects they were involved in and to specify their perceived critical success factors (CSFs) of risk management in PPP projects. The questionnaire survey was handed out to the workshop participants as well. It has been highlighted by most respondents that risk management capability and project development environment are the most important factors that would have an impact on final risk management performance of the project. It has also been admitted across the board that the success of effective risk management in PPP projects depends on the mechanism for making right parties responsible for right risk. The role of project managers and contemporary project-based management approach become pivotal in such project development environment.

SOUTHERN CROSS STATION – A CASE STUDY

Melbourne's Southern Cross Station (SCS) redevelopment project is currently the largest PPP project in Victoria worth AU$700m. This station is notable for the architectural design of a unique roof to cover the railway platforms. The roof was initially conceived as an environmentally performing element to facilitate the extraction of the diesel fumes expelled from the trains without recourse to mechanical ventilation. This roof, which has a two-way curvature and measures a massive 4.2 hectares, presented a major design and construction challenge owing to the requirement that the station had to continue full operation during construction, moving over 55 000 people per day through it. With the adoption of *Partnerships Victoria* policy in this project, it is expected that the exposure of governments adopting PPP models to risks such as cost and time overruns is minimized. The State Rail Authority of Victoria was set up to operate the station's rail function on the government's behalf. The Civic Nexus consortium, led by ABN AMRO, won the bid in July 2002. The major stakeholders involved in the project are illustrated in Table 1.

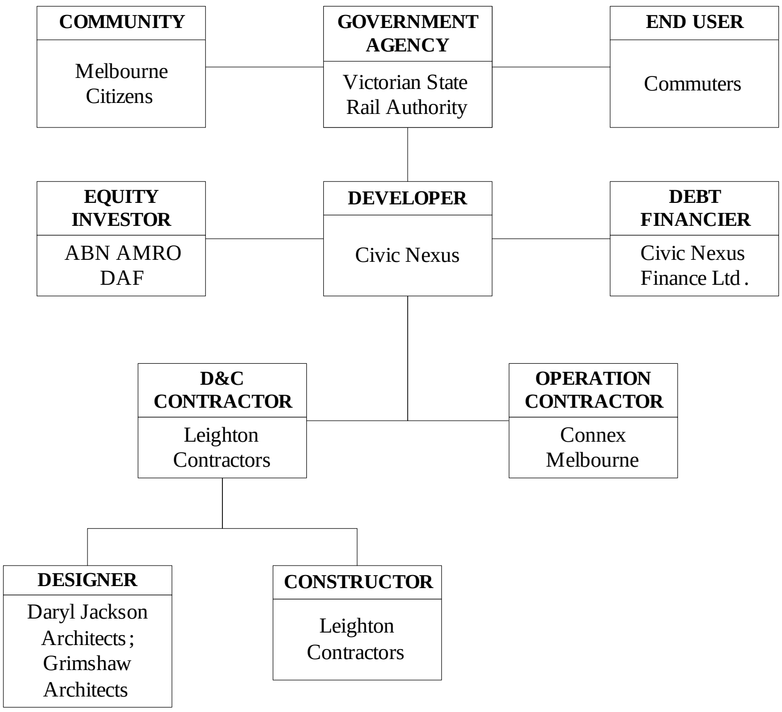


Figure 1: Major stakeholders in Southern Cross Station redevelopment project

OBSERVATIONS AND FINDINGS

The observations on the key challenges and technical difficulties in SCS project delivery presented in following section are an excerpt from the structured interviews with the key project managers in the project.

In the SCS project, the requirement of continuing station operation and the unique design of the wave-like roof limited the construction methods available. Civic Nexus (CN) and Leighton Contractor (LC) initially proposed that the work could be done at nights and weekends, which would cause minimum disruption to the ongoing operation. Though quite attractive in theory, it later became apparent that the proposal did not work in practice. The roof was much more difficult to build than CN and LC had envisaged in the design. Finally, the roof structure had to be designed as a prefabricated entity with structurally stable components. These components were cleared of tracks and associated infrastructure including overhead electrified wires during erection when the train station was not running. It was impossible to prop the roof during its construction and hence the roof columns had to be rigid enough to provide lateral stability. As a result, the size of the prefabricated structural elements had to be maximized to minimize the required number of structural lifts during construction. Besides, pre-finishing had to be maximized prior to erection to minimize the time spent in finishing the structure once it was in place.

LC's operating time was severely restricted by some work on the unique wave-roofed building, which could only be done when trains were not running. LC was thus in conflict with train operator Connex Melbourne (CM), who wanted to keep the trains running as much as possible, over the access to the construction site (Tomazin and Myer 2006). By May, 2004, LC cited the confined working environment, site access issues, the demands of the franchisee train operators, and the complex design variations as the major causes of their problems. This conflict remained unsolved, turned into dispute and LC ultimately made a claim on the resultant losses. In the SCS project, construction risks were entirely transferred by the government and then by CN to LC via a fixed term and fixed price design and construction (D&C) contract. Moreover, LC provided $60 million in case there were construction overruns or failures. Interestingly, the disputes that should have been between CN and LC become issues between the Rail Authority (RA) and LC. More surprisingly, the State government agreed to compensate LC for the cost and time overruns though the construction risks had been transferred at the cost of risk premium.

Apparently, the construction risk in the SCS project turned out to be critical and did materialize and impact on construction outcomes. As illustrated in Table 1, various parties are closely related to risks in the construction phase. A thorough analysis and quantification were necessary though it is beyond the scope of this paper.

THE PPP RISK MANAGEMENT FRAMEWORK

Once a PPP is underway, governance of its life cycle is complex and occurs across a number of processes: initial project development, briefing, calling for expressions of interest (EOI), tendering and bidding, tender selection, financing, design, design development, construction documentation, construction, operation, maintenance and finally, at some point in the future, transfer or handover. Table 1 shows the broad risk categories encountered across the PPP life cycle. It is important to understand what monetary allowance for risk should be retained by the project's public sector promoter throughout this entire process, even into the period beyond construction delivery. This allowance is defined in this paper as retained risk. In other words, this is the risk that a public sector promoter does not allocate to others but retains. In a sense this is a contingency allowance: an amount of money to be retained to allow for unforeseen circumstances across the PPP life cycle.

With regard to these risk factors during the concession period it is important first to consider how much these risk factors might affect the volatility of the facility's future cash flows. The sensitivity modelling of risk factors in social infrastructure projects is more complex than in economic infrastructure projects. This is because a greater range of factors, beyond just traffic volume, may affect the cash flows that the project delivers to its owners.

Table 1: PPP phases, broad risk categories and probable impact (Doloi and Raisbeck 2007a)

Broad risk category	**PPP phase**									
	Project development	**Briefing**	**EOI's**	**Tendering and bidding**	**Tender selection**	**Financing**	**Design development**	**Construction & documentation**	**Operation & maintenance**	**Handover**
Project risks	X			X			X	X		
Govt related	X	X	X					X	X	
Client related				X		X				
Design related							X	X	X	X
Contractor related									X	X
Consultant related									X	X
Market related							X	X	X	X
Post-construction									X	X

The types of factors that might impact on the revenue stream of the asset during the concession period include macroeconomic factors such as interest and inflation rates. But more local factors may also affect the stability of the cash flows during the concession period: e.g. the need to refit low revenue producing areas as a result of changed business conditions, the possibility of retrofitting the facility as a result of environmental issues, or the default of a long-term service contractor.

The process of delivering PPPs involves distribution of responsibility and authority to the various stakeholders involved in each PPP phase as indicated in Table 1. This process has been characterized in a way which takes into consideration a whole of PPP life approach. During the PPP process, multiple objectives such as quality performance, public satisfaction, financial return, environmental and safety performances must be reviewed for appropriate understanding of the influences on overall delivery of the project. Baldry (1998) identified a number of features embodied in committing to public sector projects, such as that the execution of the projects is rarely intended as a means to realize a pure financial reward or speculative gain; and that project function is invariably to support an operational activity or to meet a service of benefit to a large body of customers. The impact of risks extends beyond straightforward financial damage into operational disturbances, loss of service or amenity, user dissatisfaction and disruption of strategic planning processes. These features indicate that the multiple objectives in implementing a public sector project are affected by a wide range of multifaceted risks over different stages of the PPP life cycle. Thus, the risk outcomes are beyond the scope of the project itself (Shen *et al*. 2006).

A number of studies have been reported worldwide to identify risks that affect the performance of PPP projects (Li *et al*. 2005). Based on the findings of these studies, risks affecting public sector projects can be grouped into the following major categories (Shen *et al*. 2006):

- *Project-related risks*: that arise due to cost/time overruns, scope changes, poor contract management, contractual disputes and overall mismanagement of the project;
- *Government-related risks*: that arise due to inadequate project budgets, delays in obtaining permission/approvals, change of legislation, lack of coordination and bureaucrats;
- *Client-related risks*: that arise due to inadequate project budgets, ill definition of project initiation plans, oversight of project specification, inadequate cash flow and poor communication;
- *Design-related risks*: that arise due to technical project issues such as poor site access, non-standard, ambiguous and inconsistent design and change of scope/design;
- *Contractor-related risks*: that arise due to lack of experience, probity issues, loss of onsite control, poor communications, conflict between subcontractors and inadequate cashflow;
- *Consultant-related risks*: that arise due to lack of experience and expertise, oversight of the project implementation issues, performance delays, poor communication and conflicts between project owners and other project stakeholders;
- *Market-related risks*: that arise due to labour unrest, inflation, shortage of construction materials and equipments, etc.;
- *Post-construction risks*: that arise due to poor quality and service standards, customers' dissatisfaction, poor market prediction, change of ownership and consequences of conflicts and litigation between project stakeholders, etc.

As seen, though these risks spread across the project life cycle, most risks may occur during the project development and implementation phases. Figure 2 shows the consequential costs of occurrence of these risks over the project life cycle, which increase significantly as the project proceeds. The definition of consequential risk and its quantification is quite subjective. A successful project in terms of appropriate investment strategy and increased end user's satisfaction may result in significantly lower or nil consequential costs over the PPP life cycle. However, escalation of these consequential costs is a result of non-value addition activities (such as customers' dissatisfaction, tariff instability, design and functional project failures, etc.) in deemed failed projects. The remainder of the paper discusses the links between traditional construction project and PPP project management.

PPP PROJECT MANAGEMENT

Because projects are unique undertakings, they involve a degree of uncertainty. Organizations performing projects usually divide each project into several phases to improve management control. Each phase is marked by completion of one or more deliverables. Collectively, these phases are known as the project life cycle. The phase sequence defined by a project life cycle involves technology transfer or handoff such as requirements to design, or construction to operations (PMI 2001).

A PPP project life cycle has been captured in a two-dimensional chart in Figure 2. As illustrated in Figure 2, Phases III through VI describes a traditional construction project life cycle. They are as follows: (1) Initiation (and feasibility); (2) Planning (and design); (3) Execution (Construction); and (4) Closeout (Turnover and start-up). In contrast, a PPP project life cycle includes Phases I (Concept development), II (Tendering and financing), VII (Operation and maintenance), and VIII (Transfer of ownership), besides the aforementioned phases of traditional construction projects. These extra phases are rather critical to the success of PPP projects rather than peripheral. For instance, the tendering phase of PPP projects may take several years to complete, or sometimes fail, which will definitely exert far more impact on project outcome than the bidding phase of a traditional construction project does.

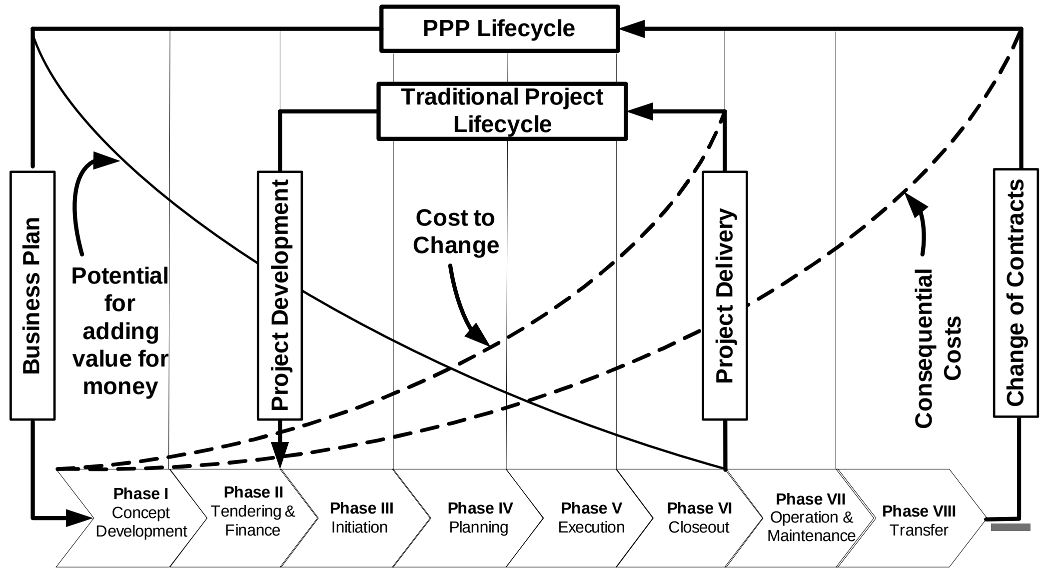


Figure 2: Consequential costs over project and PPP lifecycles

Nonetheless, the life cycle descriptions of a traditional construction project and a PPP project share a number of common characteristics:

- Cost and staffing levels are low at the start, higher towards the end, and drop rapidly as the project draws to a conclusion.
- Risk and uncertainty are highest at the start of the project and generally get progressively lower as the project continues.
- The potential of the stakeholders to influence the final characteristics of the project outcome and the final cost of the project is highest at the start and gets progressively lower as the project continues.
- The cost of changes and error correction generally increases as the project continues.

In particular, the cost of changes and error correction in a PPP project is defined in this paper as consequential cost in order to distinguish it from the similar cost in a traditional construction project. In PPP projects, such cost may include end users refusing to use the facility, and/or an adverse impact on government's reputation, which is much more substantial than the cost of changes in a traditional construction project.

CONCLUSION

The literature survey and the case study highlight the complicated and multidisciplinary management issues associated with public–private partnership (PPP) projects. The key project management issue and its contribution to large-scale transactions involving multiple stakeholders have been explored. The typical PPP life cycle phases and success–failure consequences have been illustrated over a traditional project life cycle. One of the important aspects of the PPPs is their management on two levels: government administration and private sector. Accordingly, the underlying challenges in managing and delivering PPPs from the project manager's perspective include design complexity, stakeholder integration, risk allocation and constructability issues. This research focuses on the need for management decisions on project selection and development over the whole PPP life cycle. Based on a PPP case study, risks inherent to PPP projects are categorized and the processes for appropriate identification, allocation and management of risks (both retained and transferred risks) have been discussed. It was found that the PPP projects are sensitive to good project management practices across government and private agencies. Owing to the involvement of both government and private agencies, appropriate coordination between the two parties is very important. The role of project management for the successful implementation of PPP projects helps not only to combine economic activities and resources but also facilitate successful partnerships between public and private sectors.

REFERENCES

Akintoye, A and Chinyio, E (2005) Private finance initiative in the healthcare sector: trends and risk assessment. *Engineering, Construction and Architectural Management*, **12**(6), 601–16.

Arndt, R (1999) Optimum risk transfer in build-own-operate-transfer projects: the challenge for governments. *Transactions of Multi-Disciplinary Engineering, Australia*, **GE 22**, 1–8.

Baldry, D (1998) The evolution of risk management in public sector capital projects. *International Journal of Project Management*, **16**(1), 35–41.

Brady, T, Davies, A and Gann, D (2005) Can integrated solutions business models work in construction. *Building Research and Information*, **33**(6), 571–9.

Coulson, A (2005) A plague on all your partnerships. *International Journal of Public Sector Management*, **18**(2), 151–63.

DFA (2005) *Public private partnerships: guideline: Commonwealth policy principles for the use of private financing: introductory guide*, Financial management guidance. Canberra, Australia: Australian Department of Finance and Administration (DFA).

Dixon, T, Pottinger, G and Jordan, A (2005) Lessons from the private finance initiative in the UK: benefits, problems and critical success factors. *Journal of Property Investment and Finance*, **23**(5), 412–23.

Doloi, H and Raisbeck, P (2007a) Developing a framework of retained risk in public–private partnership (PPP) social infrastructure projects. Paper presented at the 4th International Structural Engineering and Construction Conference, Grand Hyatt Melbourne, Australia.

Doloi, H and Raisbeck, P (2007b) Managing risks in public–private partnership (PPP) projects. *Taiwanese Project Management Association Journal of Project Management* (forthcoming).

DTF (2000) *Partnerships Victoria*. Melbourne, Australia: Victorian Department of Treasury and Finance (DTF).

Duffield, C F (2001) *An evaluation framework for privately funded infrastructure projects in Australia*, Unpublished PhD Thesis, Department of Civil and Environmental Engineering, The University of Melbourne.

Hayford, O (2006) Successfully allocating risk and negotiating a PPP contract. Paper presented at the 6th Annual National Private Public Partnerships Summit, 16–17 May 2006, Australia.

Jay, C (2005) PPP's fail public interest test. *Australian Financial Review*.

Jin, X-H and Doloi, H (2007) A theoretical framework for optimizing risk allocation and management in public–private partnership projects. Paper presented at the 4th International Structural Engineering and Construction Conference, Grand Hyatt Melbourne, Australia.

Johnston, S, Gostelow, P and Jones, E (1999) *Engineering and society: an Australian perspective*. 2ed. South Melbourne, Vic.: Addison-Wesley.

Leiringer, R and Green, S (2005) Products and services: is there a case for integrated solutions in construction? *In*: A Pietroforte and F Polverino (Eds.) *International Symposium – Construction in the XXI Century: Local and Global Challenges,* 18–20 October 2006, Rome. CIB Working Commissions W55, W65 and W86.

Li, B, Akintoye, A, Edwards, P J and Hardcastle, C (2005) Critical success factors for PPP/PFI projects in the UK construction industry. *Construction Management and Economics*, **23**(5), 459–71.

Mattar, M H and Cheah, C Y J (2006) Valuing large engineering projects under uncertainty: private risk effects and real options. *Construction Management and Economics*, **24**(8), 847–60.

Millar, R and Moynihan, S (2006) Major projects fail to harness precious resource. *The Age*, Melbourne, Australia.

Miners, S, Clarke-Lewis, M and Taplin, B (1995) Australian infrastructure investment: how much is enough? Paper presented at the 24th Conference of Economists, 25–27 September, Adelaide, Australia.

OECD (1991) *Urban infrastructure: finance and management*. Paris: Organisation for Economic Co-operation and Development (OECD).

PMI (2001) *A guide to the project management body of knowledge* (PMBOK guide). 2000 ed. Newtown Square, Pennsylvania USA: Project Management Institute.

Shen, L-Y, Platten, A and Deng, X P (2006) Role of public private partnerships to manage risks in public sector projects in Hong Kong. *International Journal of Project Management*, **24**(7), 587–94.

Tomazin, F and Myer, R (2006) Spencer St dispute leads to $33m bill. *The Age*, Melbourne, Australia.

Zhang, X (2005) Concessionaire's financial capability in developing build–operate–transfer type infrastructure projects. *ASCE Journal of Construction Engineering and Management*, **131**(10), 1054–64.

RISK MODELLING OF SUPPLY AND OFF-TAKE CONTRACTS IN A PETROLEUM REFINERY PROCURED THROUGH PROJECT FINANCE

Tony Merna[1] and Yan Chu

School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Manchester, UK

The procurement of refinery projects is a high-risk venture. Determining how to finance a refinery and manage typical risks in order to get sound economic returns is a major challenge. There are significant risks exposed in refinery business environment, for instance construction risk, demand risk, operation risk and especially price risk on both demand and supply sides. Availability and characteristics of types of crude oil supply and product derivatives can determine the choice of refinery types. Apart from buying crude oil in the spot market and selling its products on a similar basis, it is necessary to create significant price certainty to ensure a robust cash flow is achieved. The supply contract and off-take contract can be used to create sufficient certainty of price, quantity and availability of both crude oil and sales of refined products, and thus ensure the financial viability of a refinery project. A mechanism for assessing the risks associated with procuring a refinery is presented and an evaluation of the economic parameters modelled in Visual Basic, Crystal Ball and Excel spreadsheets is illustrated. The paper provides a case study of a refinery procurement utilizing a number of bundles of crude oil supply contracts and off-take contracts.

Keywords: cashflow, contract, modelling, risk, simulation.

INTRODUCTION

For the last three decades, the oil industry has been burdened with surplus refining capacity, often resulting in low margins. Projects procured using project finance were developed primarily for cogeneration projects, typically undertaken by independent power producers. Compared to refining projects, the technology used in cogeneration projects is known and well proven, and project profitability is reasonably predictable (Jenkins 2005). By comparison, the hydrocarbon industry is far more uncertain. Apart from typical risks in a refinery, the different types of crude oil characteristics can significantly influence refinery cash flow.

FINANCING A REFINERY PROJECT

Financing a modern refinery is a risky business. In oil and gas projects, risks can be identified in both upstream and downstream phases respectively (Merna and Al-Thani 2005). Typical risks faced by a refinery business are illustrated in Figure 1.

Project finance requires that the risks identified during the project life cycle are mitigated before sanction of a refinery and sufficient revenues can be generated to service the debt and make an acceptable profit (Merna and Njiru 2002). Typically, the

[1] anthony.merna@manchester.ac.uk

financial instruments used in a project financing are debt, mezzanine (bonds) and equity. The higher-risk projects should normally take more equity to protect the interests of lenders and bond investors and lower-risk projects can accommodate more debt (Merna and Khu 2003).

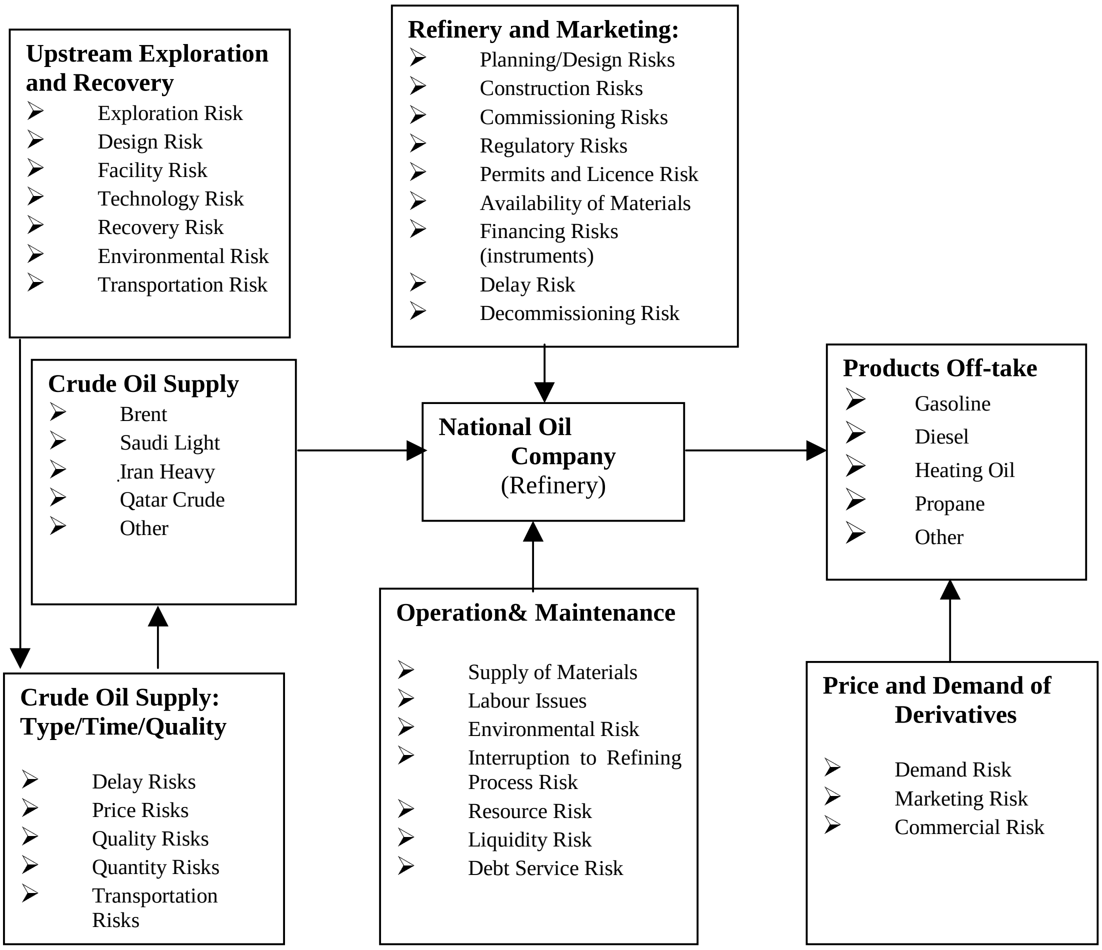


Figure 1: Typical risks in the construction and operation of a refinery

A major risk in refinery operation is associated with the characteristics and quantities of the crude oil supply, which can significantly influence refining margins. Refining low American Petroleum Institute (API) gravity crude oils requires more complex and expensive processing equipment, more processing stages and more energy; therefore, it costs more. The price difference between high-gravity and low-gravity crude oils reflects the refining cost difference. Investment in facilities to process heavier crude oils could allow refiners to improve their profits by reducing the cost of their crude oils.

Each type of crude oil will produce different percentages of refined product. Buying cheaper heavy crude oil, for example, will have a high conversation cost to light products compared to buying expensive light crude oil which is cheaper to refine. Mixing a percentage of heavy crude with light crude oil is often used to refine at a lower cost. Therefore, the price difference between light and heavy crude oils and light and heavy products are among the most important variables affecting refinery margins. These differentials are incentives for installing expensive processing facilities in a refinery, including fluid catalytic cracking, hydro-cracking, coking and other residual conversion facilities.

BUNDLING CRUDE OIL CONTRACTS

Bundling is the grouping of projects, products or services within one managed project structure in a manner that enables the group to be financed as a simple entity (Frank and Merna 2003). Similarly, bundling can be also used to bundle crude oil supply contracts to produce the optimum off-take contracts, in terms of refined products.

Modern petroleum refineries are designed to process a variety of indigenous and imported crude oils. Selecting supply contracts is crucial for companies as major costs are involved in purchasing raw materials (Bansal 2006). As the crude oil cost is about 90% of the refinery input cost, the selection of an optimum crude mix is extremely important to achieve higher margins. However, the number of options for buying crude oils under fluctuating prices and transporting them to refineries are huge, thus making evaluation of the crude oil mix extremely difficult

Refineries normally purchase crude oil and sell its products on term contracts from forward and future market and by spot purchases from the spot market. If, for example, a refinery depends on the spot market for supply, then its profit margin could be seriously affected by movements in market prices. Apart from buying crude oil in the spot market and selling its products on a similar basis, it is necessary to create significant price certainty to ensure a robust cash flow is achieved. Using a project finance strategy, the refiner would be required to enter into supply contracts to reduce spot market risk. A typical supply contract and off-take contract is arranged in a petroleum refinery project procured through project finance as Figure 2 illustrates.

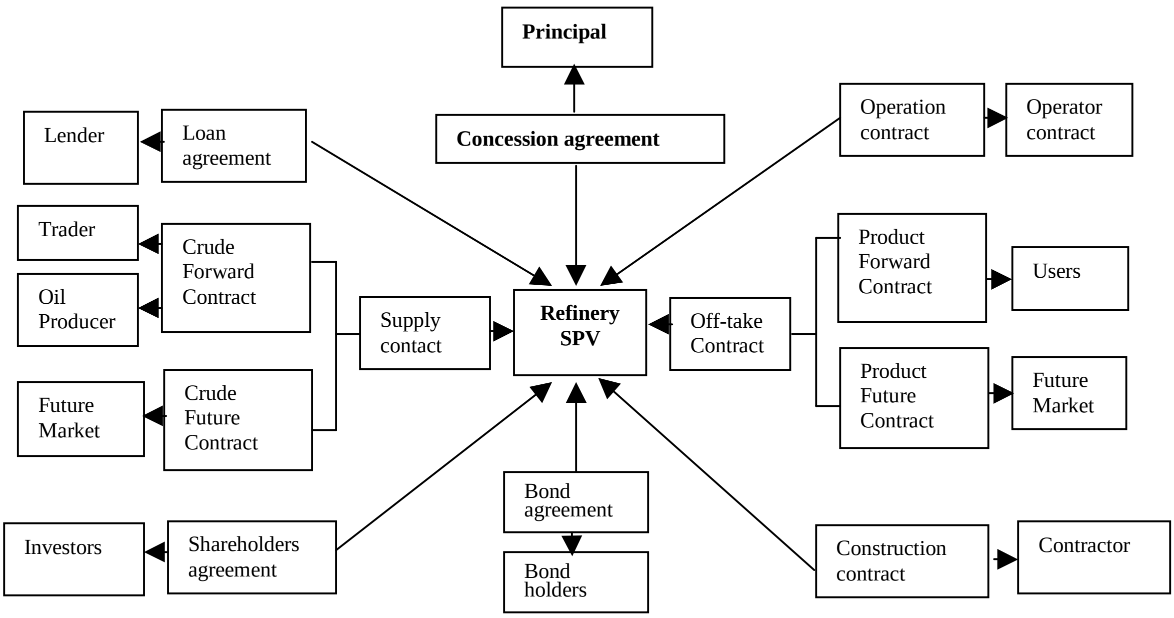


Figure 2: Contractual structure of a refinery procured through project finance

Long-term supply and off-take contracts (forward contracts) can be employed in the bundling of supply contracts to determine the cost and price structure of the off-take contracts as illustrated in Figure 3. The principal aim of the supply and off-take contract is to create sufficient certainty of price, quantity and availability of both crude oil and sales of refined products, and thus ensure the financial viability of a refinery project. It is the supply contracts and off-take contracts for refined hydrocarbons that provide the guarantee on which a “project finance” transaction is based (Elsey and Hurst 1996).

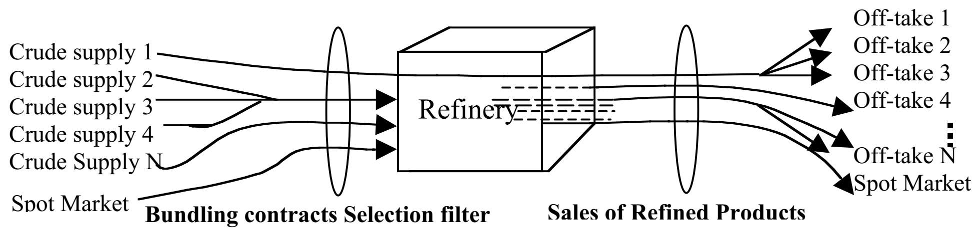


Figure 3: Typical bundling of supply contracts and their product sales

ASSESSING A CASE STUDY

The authors use a case study to assess the risks and financial viability of a refinery project procured utilizing project finance. The refinery is designed to refine both heavy crude oil and light crude oil. The characteristics of the project are show in Table 1.

Table 1: Refinery project characteristics

Location Kalamayi XinJiang Province, China
Sponsors: SINOPEC and CNPC,
Project start: 01/01/2007
Construction Completion:09/2012
Concession Period 29 years
Estimated Construction Investment: (5Years) $710 million
Estimated Operation and Maintenance Cost (24 years) $ 32500 million
Expected profits $1350 million per year
KEY Players: SINOPEC and CNPC, Kelamayi Petroleum.
Possible crude supplies:
Daqing, XinJiang, Saudi Light (Saudi L), Iran Light (Iran L), Iran Heavy (Iran H)

The refinery can refine five possible crude oils from suppliers located near to the refinery. In this mechanism, Crystal Ball is employed to assess the crude oil history data, which can be obtained from the EIA database against probability distribution by using one of several standard goodness of-fit tests. The distribution with the highest ranking fit is chosen to represent crude oil data. It is found that lognormal distribution fits Iran H crude spot market price. However, if a crude oil supply is purchased on a long-term basis and its products sold on a contract led basis, the crude oil price and refined product price are bounded. Dependencies often do exist between two variables in the system being modelled (Rodriguez 2005). When crude oil prices increase then its Gross Product Worth (GPW) increases. Clearly, they have positive correlation. Thus, the triangular distribution is assigned to this supply – off-take agreement as Figure 4 shows.

Figure 4: Iran H price triangular distribution assumption with supply contract

The risks identified have direct impact on the cost of each activity in the model: for instance, the change in construction would increase or decrease the distillation plant cost between 99.6% and 103% respectively. The deterministic cost of each activity is calculated based on those ranges. However, the economic parameters with deterministic values do not reflect uncertainties in the refinery industry. Probabilistic analysis by means of Monte Carlo simulation can deal with this problem. Thus, both range and distribution can be assigned to those variables.

The same principle can be used in other variables such as refining cost, refining margins. A triangular distribution is commonly used in the model where variable distributions are not well known but can be bounded, such as construction cost, transport costs, power and operating costs. These distributions and associated scenario input values are called assumptions.

Computing refining margin varies from refinery to refinery. To simplify the computation Gross Product Worth (GPW), crude oil prices and their GPW are imported directly from EIA database into the model.

The bundle of crude oil supply contracts and respective off-take contracts can be determined by the analyst. The decision variables – for example, the percentages of crude oil procured – are variables that can be controlled by the refinery with corresponding constraints for lower and upper bonds.

Test 1
Figure 5 shows the probability analysis for the refinery with a 100% Daqing crude oil supply (with combination of Forward Contracts, future contracts and spot market purchase) and six off-take products over a 16-year operation period. The cumulative probability diagram shows there is 85% likelihood that the IRR will not exceed 21%, with 15% probability that the IRR would be less than 4%. This result shows that there is great financial uncertainty accompanying the project.

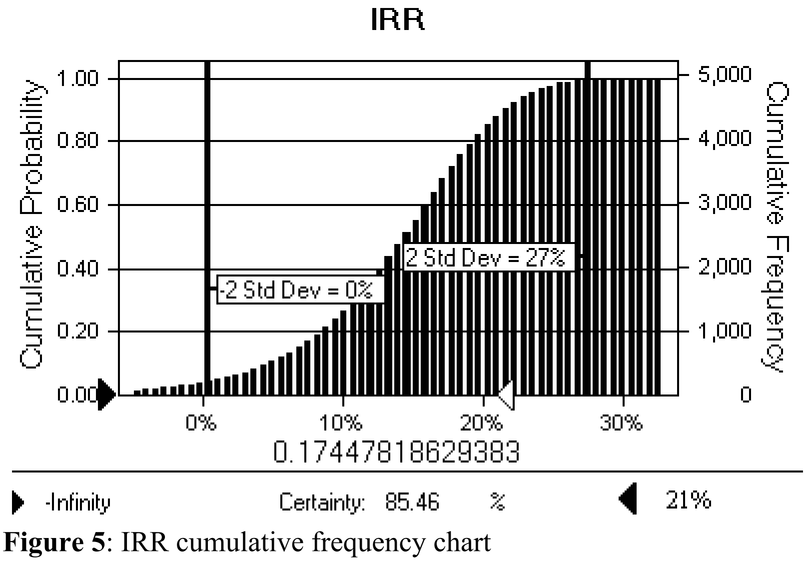


Figure 5: IRR cumulative frequency chart

Figure 6 illustrates the results of a sensitivity analysis. Curves with steep slopes, positive or negative, indicate that those variables have a large effect on the projects financial viability, whilst curves that are almost horizontal have little or no effect on the projects financial viability. Although the Daqing supply contracts and its off-take products contracts are in place, it was found that the project is still very sensitive to the crude price risk, supply default risk, supply delay risk, construction risk and GPW risk, and less sensitive to changes in refining the Daqing crude oil and design risk.

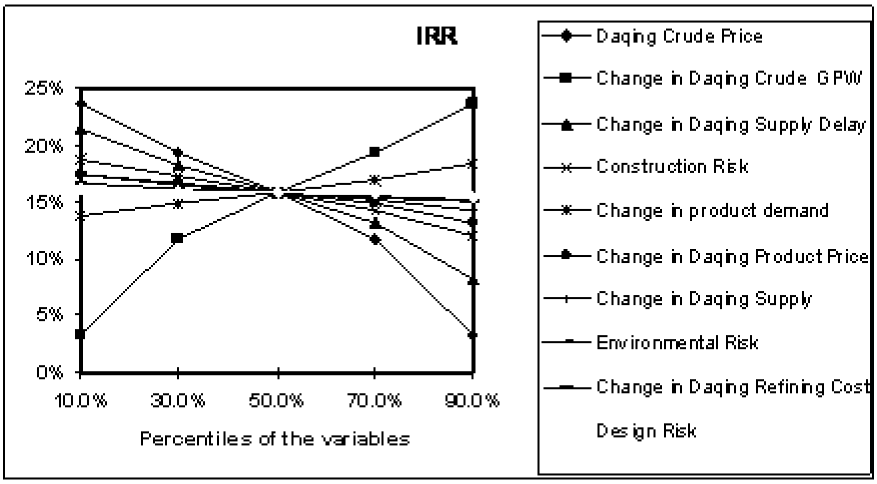


Figure 6: Sensitivity spider chart when taking Daqing crude oil supply

Table 2 and Figure 7 indicate the economic parameters and cumulative cash flow when assessed on a stochastic basis. The IRR for the base case is 16.7% and for the best case 26%; however for the worst case it is only 4%. Clearly, the project is risky with wide variation between the worst and best-case cash flow in the operation period, as illustrated in Figure 7, for a single Daqing crude oil supply.

Table 2: Economic parameters of benchmark crude supply

Economics parameter	Base Case	Best Case	Worst
NPV(Million $)	1378.49	2933.45	88.87
IRR (%)	16.7	26	4
Payback period (year)	7.92	6.71	16.22
Discounted Payback period	8.31	7.53	16.62
Cash Lock UP(m$)	-713,66	-676.21	-897.06
Discounted Cash Lock UP(m	-699.50	-659.23	-872.22
Discount Rate (%)	3	3	3

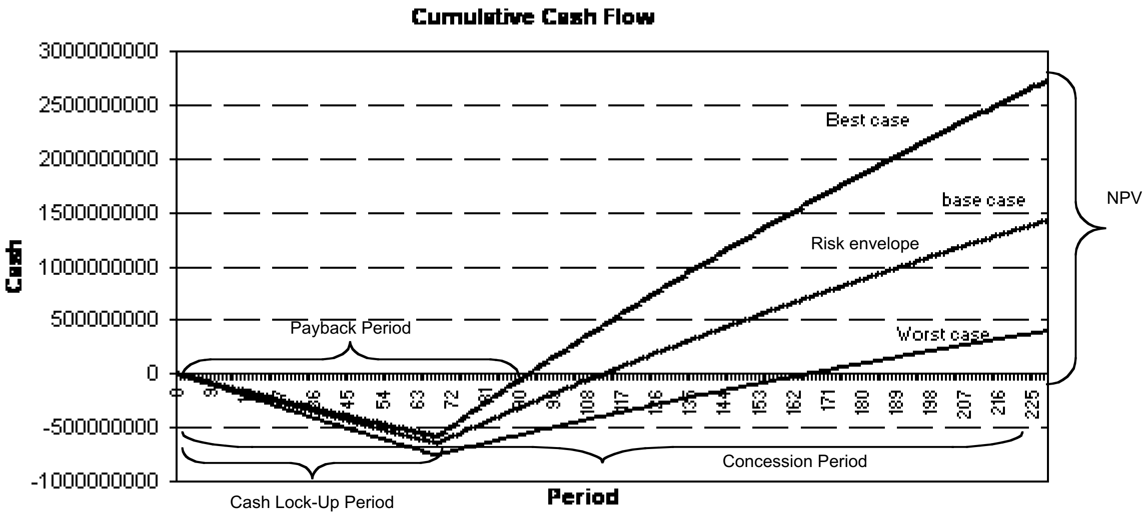


Figure 7: Cumulative cash flow of benchmark crude supply

A similar stochastic simulation process is also applied to four other possible crude oil supplies. Table 3 shows the economic parameters for each single supply. Xinjiang crude, for example, has competitive advantages such as low purchase price and low transport cost because of its location and availability to the refinery, resulting in less supply risk and price risk than other crude supply contracts.

Table 3: Summary of economic parameters of single crude supply

Crude supplies	Payback Period			IRR (%)			NPV (Million $)		
	Base	Best	Worst	Base	Best	Worst	Base	Best	Worst
Daqing	8.31	7.53	16.62	16.7	26	4	1378.49	2933.45	88.87
Iran H	9.03	8.29	13.11	15	17	13.5	1135.2	1806.44	645.5
Saudi L	12.93	7.98	Fail	9	18	1.9	507.03	1978.03	39.00
XinJiang	8.35	7.38	13.29	17	25	11.5	1387.62	2601.72	630.01
Iran L	7.42	7.13	17.2	26	29	2	1420.50	3003.05	32.01

(Note: the negative rate of return means that you cannot recover your initial investment by the end of concession period.)

Sensitivity analysis results show that most single crude oil supplies are sensitive to changes in supply, crude price, demand and GPW. The results of probability analyses of other single crude oil supplies are shown in Table 4. Clearly, there is greater financial uncertainty accompanying the project if the refinery takes a single crude oil supply. Thus, apart from the single Xinjiang supply, the other crude oil supply would be unattractive to investors when such risks were taken into account.

Table 4: Summary of probability analysis results for crude oils

Probability/Supplies	Daqing	Iran H	Saudi	Xinjiang	Iran
85% likelihood IRR not	21%	19%	15%	22%	21%
15% Likelihood IRR Less	3.5%	1.9%	1.2%	7.1%	3.2%

The same testing process is employed to test two types of crude oil supplies (Test 2), then three (Test 3), four (Test 4) and five types (Test 5). The decision in these tests is to determine the percentage of each crude oil the refinery should take to maximize the IRR and return whilst maintaining an acceptable level of risk. The constraint in those tests limit the total crude oil procured per day at no more than the refinery capacity of 220,000 b/d. Investors expect the maximum mean IRR for the minimum risk. Thus, the objective of a bundle of crude oil supplies is set to maximize the mean IRR with a standard deviation between 0.030 and 0.039.

Summary of results of Tests 2–4

It was found after a number of simulations that a combination of 75% Daqing and 25% Xinjiang crude provides the highest mean IRR in Test 2. In Test 3, if the refinery took Saudi L supply it would significantly increase risk on both supply and off-take sides in the bundle.

In Test 4, when the fourth crude supply (Iran H) was then added to the bundle and tested in the model, the bundle became more attractive than other solutions. This is because the risks associated with the fourth crude oil supply balanced the total risks on both supply and off-take sides and thus overall supply risk.

Test 5

The fifth test combines five crude oil supplies. Table 5 illustrates a bundle of 10% Daqing, 25% Iran L, 50% Xinjiang, 20% Iran H and 0% Saudi L as providing the highest return with higher risk than previous tests.

Bundle analysis

The analyses show that there is no perfect bundle solution. Some bundle solutions such as 100% Xinjiang has relatively lower return with a lower given risk, whereas some bundles have higher return with relatively higher risks. However, the best bundle of crude oil supply contracts and off-take contracts should be determined by the level of risk acceptable. Efficient frontier analysis is then employed to consider the balance between return and risk in selecting the optimal crude supply contract bundle based on the risks identified.

Table 5 illustrates Mean Return and standard deviation for combinations of crude supply contracts of a bundle of the five crude oil supplies tested. Under certain risk levels, different bundle will generate different returns.

Table 5: Solutions of mean return and standard deviation for combinations of five crude supply contracts

Solutions	Proportion Daqing %	Proportion Saudi L %	Proportion Xinjiang %	Proportion Iran H %	Proportion Iran L %	Maximize IRR Mean	Standard Deviation<=[0.03,0.06]
1	0	0	100	0	0	0.167	0.03
2	59	0	7.0	34	0	0.19	0.033
3	75	0	25	0	0	0.22	0.036
4	40	0	25	30	10	0.24	0.037
5	10	0	50	20	25	0.25	0.038

Figure 8 shows the efficient frontier for the bundle of five crude oil supplies. The efficient frontier is the intersection of the set of bundles with minimum variance (risk) and the set of bundles providing the maximum return. For example, a bundle of 59%Daqing, 0% Iran L, 0% Saudi L, 7.0 % Xinjiang and 34% Iran H crude oils is more efficient than the bundle of 61%Daqing /39%Iran H in Test 2 because it has a higher IRR and NPV although both of them are exposed to a similar risk level.

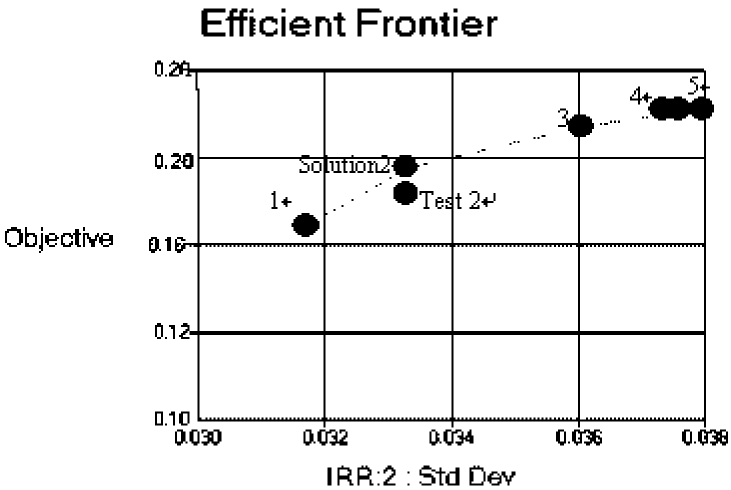


Figure 8: Efficient frontier

Bundle solutions after risk mitigation

When the bundle forming the efficient frontier was simulated new economic parameters were generated, as shown in Table 6. The risks associated with this bundle were then assessed. The risks associated with supply contracts were analysed and it was found that crude supply risks in Solution 3 (shown in Table 5) are more difficult to manage than Solution 4. Tables 7 and 8 illustrate that after risk mitigation, Solution 4 is more attractive to investors than Solution 3 because the risk level of Solution 4 can be reduced to the same risk level as Solution 3 but with high returns Therefore, Solution 3 is no longer on the efficient frontier after risk mitigation.

Table 6: Summary of economic parameters of five crude supplies

Crude supplies	Payback Period			IRR (%)			NPV (Million $)		
	Base	Best	Wors	Base	Best	Worst	Base	Best	Worst
100%XinJiang	8.35	7.38	13.29	17	25	11.5	1367.62	2601.72	630.01
59%Daqing0% Iran L 34%Iran H	8.2	7.9	14.96	19	28	11.02	1388.08	2796.76	572.0
75%Daqing 25%Xinjiang	8.3	7.5	15.23	21	29	10.5	1422.0.0	2933.7	552.0
15%Daqing, 0%Saudi L, 35% Xinjiang, 30%Iran H, 20%Iran	7.79	7.23	15.29	23	31.	10.1	1800.16	3328.78	546.0
10%Daqing, 25%Iran L, 50%Xinjiang, 20%Iran H, 0%	7.5	7.0	16.21	25	33	9.95	2500.25	3956.0	540.0

Table 7: Mean return and standard deviation for combinations of crude supply contracts after risk management

Solutions	Proportion Daqing %	Proportion Saudi %	Proportion Xinjiang %	Proportion Iran H %	Proportion Iran L %	Maximize IRR Mean	Standard Deviation<= [0.03,0.06]
1	0%	0%	100%	0%	0%	0.169	0.029
2	59%	0%	7.0%	34%	0%	0.20	0.031
3	75%	0%	25%	0%	0%	0.23	0.035
4	40%	0%	25%	30%	10%	0.24	0.035
5	10%	0%	50%	20%	25%	0.26	0.037

Table 8: Economic parameters after risk management

Crude supplies	Payback Period			IRR (%)			NPV (Million $)		
	Base	Best	Worst	Base	Best	Worst	Base	Best	Worst
XinJiang 100%	8.26	7.28	13	17	25.5	12	1367.62	2791.72	640.01
59% Daqing, 0% Iran L, 34% Iran H, 0%Saudi L, 7.0 %Xinjiang	8.2	7.7	13.9	19	29.5	12.5	1588.08	2996.76	869.0
75%Daqing 25%Xinjiang	8.3	7.2	14.0 3	22	31	12.9	1622.0	3433.7	899.0
15% Daqing, 0% Saudi L, 35% Xinjiang, 30% Iran H, 20% Iran L	7.5	7.23	15.19	24	31.5	11.1	1800.16	3528.78	765.0
10% Daqing, 25% Iran L, 50% Xinjiang, 20% Iran H, 0% Saudi L	7.5	6.9	15.21	25	34	10	2500.25	4256.0	656.9

The analyses show that the project is exposed to different levels of risks and different economic returns. After risk mitigation, Solution 5 still has highest return with highest risk; Solution 1 has lowest economic return but lowest risk. Investors choosing Solution 1 would seek a large amount of debt; whereas investors choosing Solution 5 would require more equity as risk finance.

CONCLUSIONS

The authors simulated a bundle of supply and off-take contracts and compared different economic outputs from each bundle.

The assessment clearly illustrates the bundles best, worst and base-case economic parameters with impact of both supply risk and typical refinery risks.

The assessment offers a detailed method for determining the crude oils to be purchased and their percentage within a bundle of crude oil supply contracts.

The assessment can aid stakeholders in the decision making process regarding the type and quantity of crude oil supply contracts based on identified risks.

Investors in refinery projects can assess specific risks affecting crude oil supply in relation to the overall project economic parameters.

There are numerous combinations of crude oil supply bundles. The risks associated with supply and off-take is extremely complex. From the tests shown in the analyses, the refinery economic viability is very sensitive to the crude oil supply and off-take. The choice of a bundle of crude oil supplies is paramount to the commercial viability of a refinery thus making risk management an integral part of refinery procurement and operation.

REFERENCES

Bansal, M and Scrinivasan R (2006) Modelling and Selection of Supply Contracts. *In: National University of Singapore, the 2006 Annual Meeting*, San Francisco, CA.

Derivatives and Risk Management in the Petroleum, Natural Gas, and Electricity Industries, (2007) EIA (date accessed January 2007). Available online: http://www.eia.doe.gov/

Ellafi, J and Merna, T (2005), *Investigating the Finance Strategies for Gas Projects in developing countries*, PhD thesis, Faculty of Engineering and Physical Science, School of MACE, University of Manchester.

Elsey, M and Hurst, P (1996) *Projects Procured by Privately Financed Concession Contracts*. Hong Kong: Asia Law and Practice Ltd.

Frank, M and Merna, T (2003) Portfolio Analysis for a Bundle of Projects. *Journal of Structured and Project Finance*, **9**(3), 80–7.

Jenkins, J H (2005) *Off-Balance-Sheet Financing to the Refinery Industry*. Croydon: Jacobs Consultancy.

Merna, T and Al-Thani, F (2005) *Corporate Risk Management, an Organisational Perspective*. Chichester: John Wiley & Sons Ltd.

Merna, T and Khu, F L S (2003) The Allocation of Financial Instruments to Project Activity Risks. *Journal of Structured and Project Finance*, **8**(4).

Merna, T and Njiru, C (2002) *Financing Infrastructure Projects*. London: Thomas Telford.

Refining, S G T (date accessed April 2006) Petroleum Refinery Planning and Optimization Using Linear Programming.

Rodriguez, J M A and Padua K G d O (2005) *An Application of Portfolio Optimization with Risk Assessment to E&P Projects*, Crystal Ball Conference Paper.

MODELLING RISK MANAGEMENT FRAMEWORK IN BOT PROJECTS: INDONESIA'S CASE STUDY

M. Agung Wibowo[1] and Andi Nusa Patria[2]

[1]*Diponegoro University, Semarang, Indonesia*
[2]*Indonesian Islamic University, Yogyakarta, Indonesia*

Build-Operate-Transfer (BOT) is perceived as a risk sensitive procurement method. In a limited concession time, the project sponsor (investor) is expected to achieve return on investment and profit by the end of the concession period. Theoretically, BOT investors have to manage greater scope of risks than the ones on traditional cost + fee projects. Various kinds of risk factors, such as public policy or economic environment of a country, are to be considered. This research aims to identify the risk management framework in BOT projects and develop a conceptual model to advance the use of a systematic approach to risk management. First, the existing approach to risk management in BOT projects on public infrastructure in Indonesia (bus stations and regional marketplaces) was observed and analysed. A survey targeted at experienced officials from public and private sector organizations involved in BOT projects was conducted to elicit industry opinions and implementations of risk management. Second, studies in BOT schemes and risk management theories are added to the existing approach. Based on these studies, a framework for implementing risk management in BOT project is proposed and refined on three rounds of focus group discussions. The research found that risk management processes in BOT projects have a cyclic form. These cyclic processes occur in the planning, construction and operation stages of the BOT projects. A systematic risk management framework is proposed to enhance the ability to take quantifiable and accountable measures in every project stage. This framework will enable the organization to strengthen accountability and encourage learning to ensure the continuous improvement of this model.

Keywords: Build-Operate-Transfer, modelling, risk management, framework, public facility.

INTRODUCTION

Uncertainty is inherent in all activities (Mawdesley 2003). It means that there are always possibilities to meet different outcomes compared to what is expected. Uncertainty could lead to a better or worse result than what is expected at the beginning. As the complexity of activity increases, there will be more uncertainty, and the variability of the results will be much greater.

Construction projects, especially large-scale ones, are activities of great complexity, regarding the various components used, quantity of resources involved and the uniqueness of every project. These characteristics usually result in a large number of unknown, unpredictable and unquantifiable problems leading to the development of various risks that could undermine the successful performance completion of a project (Wibowo 2005). Build-Operate-Transfer (BOT) is a project scheme whereby a private entity (investor) is granted concession for a right on certain period of time, along with

[1] agung_wibowo8314423@yahoo.co.uk

the responsibility to finance, build and operate a facility until the investor finally transfers it in a fully operable condition to the principal at no cost. The scheme is considered risk sensitive. The investor is expected to achieve a return on investment (RoI) and gain profit by the end of concession period. This relatively new procurement method (especially in developing countries) changed the way a public facility delivered, while also altering the culture of the parties involved in terms of how they perceive risks. Akintoye (1998) suggests that a private finance project (including BOT) should satisfy two fundamental requirements: securing value for money and allocating risks appropriately. Risks should be allocated into categories of those that are best absorbed and most efficiently managed by the private sector, and those that should remain with the government department. Therefore, adequate knowledge and good implementation of risk management in both parties are essential to bring more successful BOT project.

The decrease of investment growth and the quality of public infrastructure serviceability in Indonesia after the great recession in 1997 has sent a powerful message that this country's ability to finance and build facilities has also been in decline. A decelerated economy along with the absence of necessary knowledge and experience in the latest construction technology and management has necessitated the need to draw in private partners to form private finance initiative projects, including BOT schemes. Despite the encouragement to procure more BOT projects, there are needs to investigate their risk management process, and provide implementation and evaluation guidelines.

The aims of this paper are: (1) to identify the general processes within the risk management framework of BOT projects; and (2) to propose a conceptual model of risk management in BOT projects based on Indonesia's experiences.

REVIEW ON RISK MANAGEMENT

Risk, uncertainty and opportunity

Most business making takes place on the basis of expectations about future, while the future itself is largely unknown. Decisions that have been made based on assumptions, expectations, estimations and forecasts always involve risks. Risk is an abstract concept. It is difficult to define and, in most cases, it is hard to quantify in precision (Wibowo *et al*. 2005). The definition of risk stated in the *Oxford English Dictionary* (2000) is: "The possibility of meeting danger or suffering harm or loss". This definition proposes that risk is a form of incomplete knowledge about the future that could lead one to a danger of harm or loss. There is a strong relation between risk and uncertainty, where risk is a function of uncertainty. However, some people like to distinguish between risk and uncertainty. Raftery (1994) states that risk is taken to have quantifiable attributes, whereas uncertainty does not. Risk arose when it was possible to make a statistical assessment of the probability of occurrence of a particular event. Risks, therefore, tended to be insurable. An important question rises: why do we expose ourselves to uncertainty that could lead to a "possibility of loss"? Dawson (1997) explains that the logical answer must be that there is the possibility of gain and this can only be achieved if we place ourselves at risk. This proposes that opportunity and risk are both functions of uncertainty. Opportunity and risk are uncertain and therefore have a probability of occurrence and outcome.

Risk management

Risk management is the name given to a formalized process of balancing the risks and opportunities a decision may produce, and taking action to produce an acceptable balance between the two. The way in which this process is usually performed, when using subjective experience and gut feeling, is largely unknown or person specific, but certain procedures seem to be integral to it (Wibowo *et al*. 2005).

1. The uncertainties in the project or venture are identified.
2. The significance of each is assessed in terms of consequence and chance of occurrence.
3. The risks and opportunities are balanced to show the overall uncertainty.
4. The balance produced is judged against acceptability criteria to determine the need for actions to produce an acceptable balance.
5. The actions needed are determined with reference to the significance of each uncertainty.

Regardless of the discrepancies of the definitions of risk management provided by some experts, practitioners usually implement the process by introducing steps to fulfil specific objectives or particular requirements (Dawson and O’Reilly 1999; Thevendran 2004). General processes of risk management that have been widely understood and used are risk identification, risk analysis and risk response. Robillard (2000) suggests an integrated and more comprehensive approach to risk management. He stated that it is no longer sufficient to manage risk at the individual activity level or in functional silos. Organizations around the world are benefiting from a more comprehensive approach to dealing with all their risks. Integrated risk management is a continuous, proactive and systematic process to understand, manage and communicate risk from an organization-wide perspective. It is about making strategic decisions that contribute to the achievement of an organization's overall corporate objectives.

This approach requires an ongoing assessment of potential risks for an organization at every level then aggregating the results at the corporate level to facilitate priority setting and improved decision making. Integrated risk management should become embedded in the organization's corporate strategy and shape the organization's risk management culture. The identification, assessment and management of risk across an organization help reveal the importance of the whole, the sum of the risks and the interdependence of the parts. Integrated risk management does not focus only on the minimization or mitigation of risks, but also supports activities that foster innovation, so that the greatest returns can be achieved with acceptable results, costs and risks. Integrated risk management strives for the optimal balance at the corporate level. In this approach, the risk management framework is conceived as a comprehensive process beginning with an internal look at the ability of an organization and its risk-taking characteristics to the implementation and evaluation of risk management practices. The process is described in Figure 1 below.

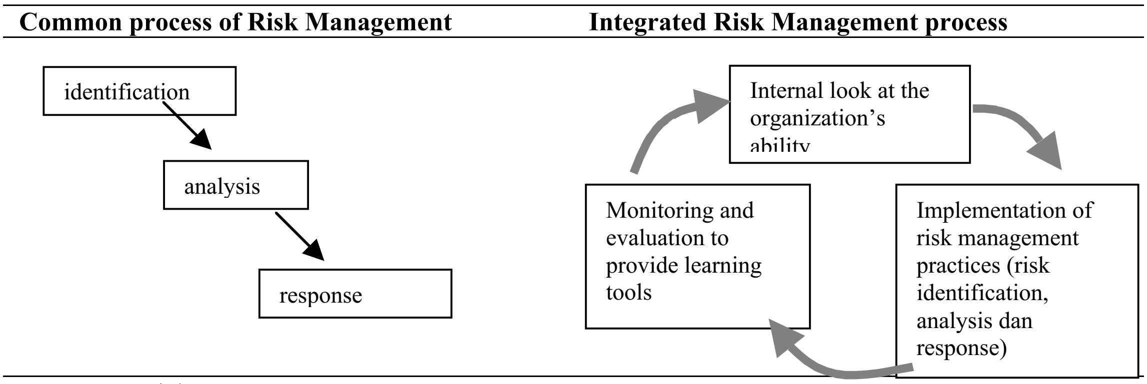


Figure 1: Risk management process

Risk management in BOT projects

BOT schemes contain large numbers of factors that may affect business uncertainty such as a long concession period, large number of parties involved and the complexity of relationships among the parties in the project itself. On the other hand, the project should run under limited resources and conditions. The factors of uncertainty combined with the limited resources and conditions have pushed managers to apply more effort in managing risks to produce more predictable results and protect the life cycle of the project itself.

Commonly, there are five stages of BOT project in which the owner and investor are involved. They are preliminary, planning and design, construction, operation and post operation. Both parties have specific roles and functions during each stage. Project stages and roles of both parties can be described as follow:

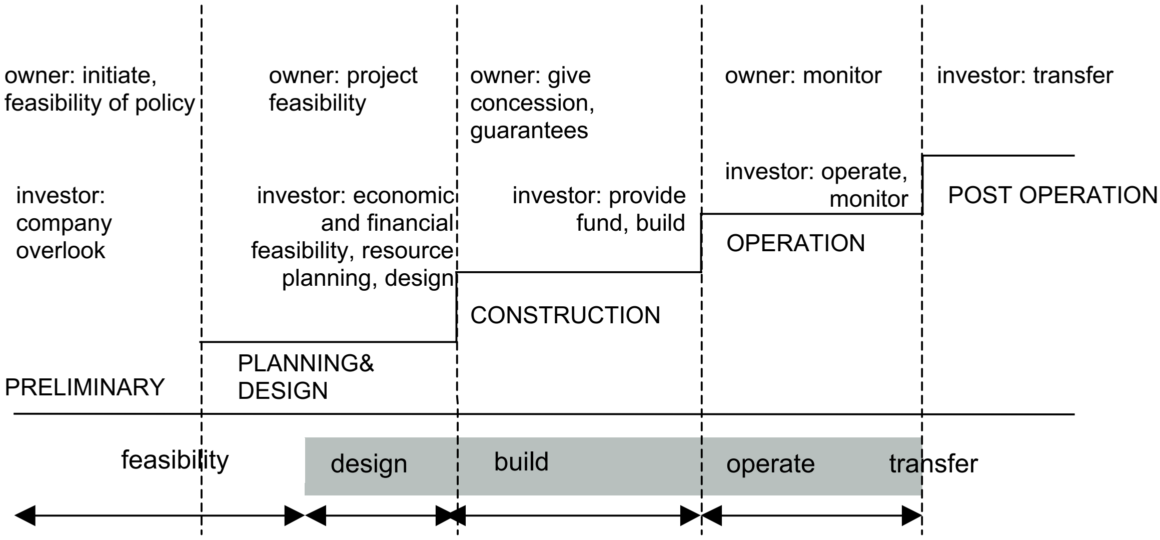


Figure 2: Build-Operate-Transfer project scheme

RISK MANAGEMENT FRAMEWORK FOR BOT PROJECTS

Studies on risk management theories show that there are common processes in risk management (as suggested in Figure 1). These common processes will be used as basic knowledge to develop a risk management framework. The common processes involved risk identification, risk analysis and risk response. This is a linear process in which identification will be succeeded by analysis, and risk response concludes these three stages.

Indonesia's BOT case

A survey was conducted on two case studies of Indonesia's BOT projects. They are Giwangan Bus Terminal and Cilacap Public Marketplace. These two projects are owned by local government and managed by a private company.

Giwangan Bus Terminal is a state-owned bus terminal in Jogjakarta City. This terminal is located on the southern side of the city, positioned to generate the area's economic growth and improve the quality of the mass transportation system. This 120 billion rupiah project will include a terminal and commercial facilities (shopping centre and hotel). The Jogjakarta City Government decided to proceed with this project through a BOT system due to the lack of investment funds needed. PT Perwita Karya, a local private company, was awarded a 30-year concession to fund, build and manage this facility.

The second case study is the Public Marketplace Project in Cilacap Region, Central Java. The project includes renovation and development of an existing marketplace. The work costs 36 billion rupiahs. As with the first case study, the Government was out budgeted. Yet, they needed to proceed with the project to promote the growth of this region's economy. Therefore, the Government invited PT Lingarjati, a public company, into a BOT arrangement to fund, build and operate the facility.

Both cases show a similar risk management framework. First, they conducted a process identified as "internal action". This is a process where owner and project sponsor prepare their organization for the project. Second, the owner hires a third party consultant to conduct a feasibility study on economic, legal and technical aspects. Meanwhile, the project sponsor assembles an internal team to conducts its own feasibility study. These studies identify risks and opportunities contained in the project. Third, risks are analysed in terms of impact and likelihood, and the ability of the organization to handle them. Fourth, the response to the risks are analysed, which includes allocating risks to one of the party considered most capable to handle them. After risks are shared, the parties involved will take mitigation measures to decrease the impact and possibility of risk occurrence. At this stage, monitoring and evaluation are consistently conducted. Results of the evaluation are used to anticipate constraints and to improve project performance. This process cycles in three phases of the project: planning, construction and operation.

The survey also shows that investors perceived the construction phase as the most risky. This may indicate their remaining mindset as contractors.

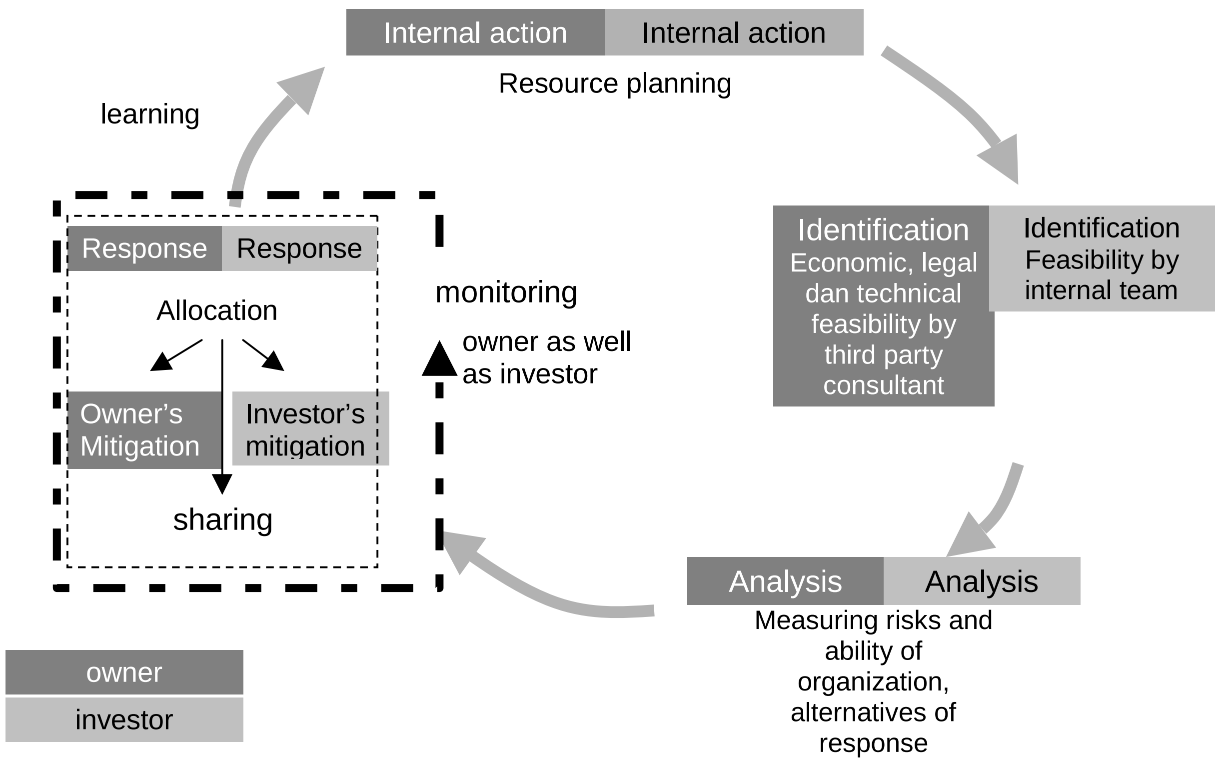


Figure 3: Risk management framework on Indonesia's BOT case

PROPOSED RISK MANAGEMENT FRAMEWORK MODEL FOR BOT PROJECTS

The proposed models are based on two areas of study: risk management theories and the case study of two public facility projects conducting BOT scheme in Indonesia. The results of these studies are compared using several parameters and combined to generate a proposed framework model. The proposed model is refined through three rounds of focus group discussions (FGDs) participated by seven Indonesian experts from government and universities. Practitioners from the public sector did not respond to the invitation of this FGD. Composition of the experts is described in Figure 4 below.

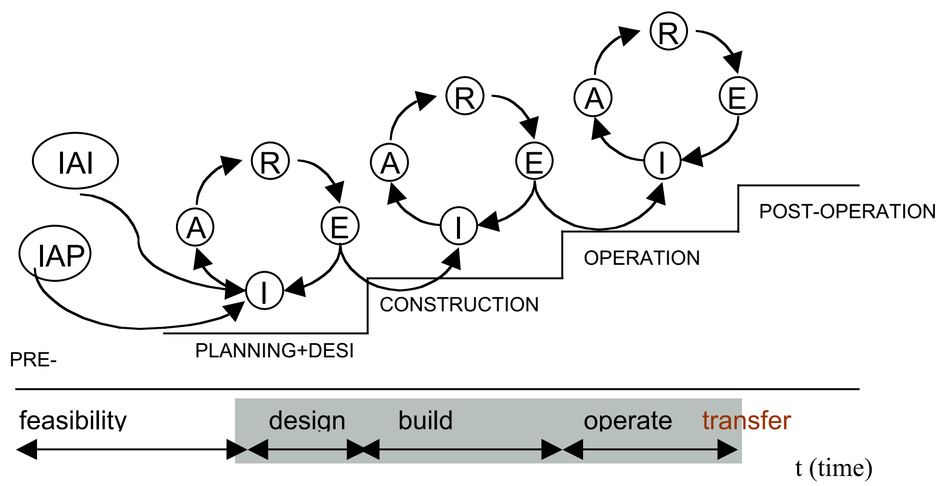
numbers of participants	**institution**	**position**
1	university	modelling adviser
3	university	private finance researchers
2	government	Head of Cooperation Department
1	government	Officer of BOT project

Figure 4: Participants of focus group discussion

Summary of the risk management frameworks in theory and case studies are compared on certain parameters as seen in Table 1. This comparison and inputs from FGDs are used to generate principles of the proposed framework model.

Table 1: Comparison of the frameworks

	Theory	**Case study 1**	**Case study 2**	**Proposed**
Schematic form	Linear	Cyclic	Cyclic	Cyclic
Process	Identification, analysis, response	*Internal action*, identification, analysis, response, evaluation	*Internal action*, identification, analysis, response, evaluation	*Internal action*, identification, analysis, response, evaluation
Management highlight	-	Construction	Planning, construction, operation	Comprehensive
Identification	Macro (country level), intermediate (market level) and micro risk (project level)	Macro (political, economic, policy) and micro risk (financial, technical, environment)	Intermediate (market, regional economy) and micro risk (financial, technical, environment)	Macro and micro risks for every stage, resource needed, stakeholders' ability
Analysis	Qualitative or quantitative	Qualitative	Qualitative	Qualitative and quantitative
Risk response	Based on identification and analysis	Consideration on feasibility study, decision on compromise	Consideration on feasibility study, decision on compromise	Feasibility study, possibility of capacity building and compromise
Monitoring	-	-by owner -by investor	-by owner -by investor	-by owner -by investor
Target of evaluation	Capability, risk handling, result	Dynamic situation of the project	Dynamic situation of the project	Capability, risk handling and result on every stage of the project
Purpose of evaluation	Find discrepancies between achievement and criteria	Learning within the ongoing process for immediate actions	Learning within the ongoing process for immediate actions	Learning tools for ongoing and future activities



IAI: internal action on investor's side
IAP: internal action on owner's side
I : risk identification
A : risk analysis
R : risk response
E : evaluation
Concession period

Figure 5: Proposed risk management framework model

The result of the comparison above indicates common practices as well as differences in some areas. However, there are some principles to be applied to propose a model of the risk management framework on a BOT project. The model consists of a common process cycle (identification, analysis, response, evaluation) that is implemented in every phase of the project (planning, construction, operation, and post operation). All processes are started by internal action on both sides (owner and investor).

The model in Figure 5 above provides a comprehensive vision on how risks are managed in BOT projects. More detailed elements of the framework are described as follow:

Internal action on owner's side
This process begins as the owner sets strategic directing. At this stage, the owner analyses the position and capability of its organization and sets a target to achieve by implementing risk management. In both Indonesian cases, the owner formed a team to conduct a feasibility study with the assistance of external teams (professional consultants). The study reported the actual condition of the organization and the environment in which the project will be implemented. The objectives of the study are (1) to identify organization's risk profile; and (2) to set the purpose and target of risk management. Once the risk profile is identified and the target is set, the organization builds a more specified structure to conduct risk management.

Internal action on investor's side
Internal action is also implemented within the investor's organization. This is basically a similar process that is taken to develop the organization's risk profile (company's risk profile) by identifying the existing risk profile and assessing the ability of the company to manage risks. To enable the risk management function to run effectively, it has to be integrated with a decision-making system. Internal action on the investor's side does not include strategic directing.

Internal action on both sides is essential to provide a good foundation on which further process of risk management will be implemented. Next, the core process of risk management is implemented. This includes risk identification, risk analysis and risk response.

Risk identification
The purpose of the risk identification process is to identify existing risks and the capability of the organization to handle potential risks. This process is conducted by both investor and owner. There are three simultaneous elements of work required in this process: (1) to observe the environment of the project; (2) to assess resources needed to implement risk management; and (3) to analyse stakeholders.

Risk analysis
Risk analysis is one of the most critical processes of risk management. Here, existing risks in every project stage are listed and measured in terms of impact and probability. Impact and probability are factors of importance level that provide guidance for the management to assign priority to the risks that concern it most. The organization's capability is also a subject taken into consideration in determining this importance level. The process can be either qualitative or quantitative. The Jogjakarta and Cilacap case implemented qualitative techniques for risk analysis.

Risk response

Risk response is a process in which risks are delivered to the parties involved in the project (risk allocation) and minimized (risk mitigation). Parties involved in the project might negotiate in this process to make an agreement on the allocation of risks. Once risks are allocated, the parties burdened shall implement mitigation strategy to minimize the impact and likelihood of risks within their sides.

Risk evaluation

The processes of risk management need to be evaluated on their capability, handling and result to find out whether they meet the target or not. This evaluation has to be communicated throughout the work environment. Evaluation of the planning, design and construction stages may result in two conditions: satisfy the target or otherwise. The first condition leads management to re-identify risks within the same stage. The second condition leads management to the next process, which is identification of risks at the next stage. If considered successful, the next process will be preparing a learning plan for the next project.

CONCLUSION

The Indonesian Government has created opportunities for the private sector to participate in the delivery of public facilities with various kinds of investment schemes, including BOT arrangements. This scheme is perceived as risk sensitive, so a comprehensive understanding in risk and risk management process in BOT projects is needed. Furthermore, BOT requires a cultural change in which a construction contractor must act as an investor. A model of risk management in BOT project helps managers to conceive an abstract process of the risk management and translate it into a schematic concept. This process is essential to build a better understanding and implementation of risk management.

The general process identified in BOT risk management consists of internal action, identification, analysis, response and evaluation. Based on this general process, a conceptual model has been proposed. The model has a cyclic form, containing a cycle of the general processes in every project stage (planning & design, construction and operation).

REFERENCES

Akintoye, A, Taylor, C and Fitzgerald, E (1998) Risk Analysis and Management of Provate Finance Initiative Projects. *Engineering, Construction and Architectural Management*.

Dawson, P J (1997) *A Hierarchical Approach to Management for Construction Project Risk*. University of Nottingham.

Miller, R and Lessard, D (2000) Understanding and Managing Risks in Large Engineering Projects. *International Journal of Project Management*/Universite du Quebec a Montreal, Canada.

Özta_, A and Ökmen, O (2003) Judgemental Risk Analysis Process Development in Construction Process. *Journal of Building and Environment*/University of Gaziantep, Turkey.

Reif, B (1973) *Models in Urban Regional Planning*. London: Leonard Hill Books.

Tambunan, F P (2003) *Pengaruh Risiko Model Project Financing pada Pola Joint Operation dengan Simulasi Monte Carlo*, Project Management Thesis, Universitas Indonesia.

Uher, T E and Toakley, A R (1999) Risk Management in The Conceptual Phase of Project. *International Journal of Project Management*/Risk Management Research Unit, School of Building, UNSW, Australia.

Umar, H (2001) *Manajemen Risiko Bisnis, Pendekatan Finansial dan Non Finansial*. PT Gramedia Pustaka Utama.

Wibowo, A M, Amudi, O and Mawdesley, M J (2005) *Risk Management dalam Private Finance Initiative*, an essay presented at National Seminar on Private Finance Initiative, Yogyakarta.

Wibowo, A (2005) *Private Participation in Transport: Case of Indonesia's Build, Operate, Transfer (BOT) Toll Roads*, dissertation, Technische Universitat Berlin.

AN EXPERIMENTAL APPROACH TO PROJECT RISK IDENTIFICATION AND PRIORITIZATION

Samuel Laryea[1]

[1] *Department of Building Technology, Kwame Nkrumah University of Science and Technology, PMB, Kumasi, Ghana*

One of the aims of a broad ethnographic study into how the apportionment of risk influences pricing levels of contactors was to ascertain the significant risks affecting contractors in Ghana, and their impact on prices. To do this, in the context of contractors, the difference between expected and realized return on a project is the key dependent variable examined using documentary analyses and semi-structured interviews. Most work in this has focused on identifying and prioritizing risks using relative importance indices generated from the analysis of questionnaire survey responses. However, this approach may be argued to constitute perceptions rather than direct measures of the project risk. Here, instead, project risk is investigated by examining two measures of the same quantity: one 'before' and one 'after' construction of a project has taken place. Risks events are identified by ascertaining the independent variables causing deviations between expected and actual rates of return. Risk impact is then measured by ascertaining additions or reductions to expected costs due to the occurrence of risk events. So far, data from eight substantially complete building projects indicate that consultants' inefficiency, payment delays, subcontractor-related problems and changes in macroeconomic factors are significant risks affecting contractors in Ghana.

Keywords: contractors, Ghana, risk, risk identification, risk impact.

INTRODUCTION

Project uncertainties create forces of risk that act in project environments to cause deviation of actual performance from the expected. Contractors may survive some levels of risk while others can result in losses and business failure. The identification of risks affecting contractors in specific construction environments and their impact on prices can help contractors to estimate a price for risk when building up prices. This study conceptualizes a novel experimental approach to identify and prioritize risks affecting contractors in the Ghana construction industry.

BACKGROUND

Much of the empirical work on risk can be described as measures of perceptions rather than direct measures of the risk. Methodologically, most work has resulted from questionnaire surveys where respondents rank risks to help researchers analyse what can be statistically described as relative importance indices. This can be argued to be measures of perceptions (what respondents claim to be the case) rather than direct measures of the project risk (the actual losses or gains incurred). Besides, three limitations can arise from this very common approach. First, mainly the positive risks that create losses often result. Second, besides the tendency of humans to forget,

[1] salaryea@yahoo.com

respondents may seek to portray a good image of company performance. Third, the results scarcely give an idea of the consequences of the risks in monetary terms.

Risk is a fact that we all face and act upon daily. However, its measurement is difficult and highly subjective. What poses risk to one organization may not pose risk to another. The problems of risk assessment are complex and poorly understood in practice. Contractors are often unable or unwilling to make appropriate allowances for the risk element in construction projects. While their inability may be due to nonchalance or a lack of expertise, their reluctance may be attributable also to a regard for the other factors that also affect price. This may include competition, need-for-work, perceived opportunities, and project characteristics. These factors may generally cause the price of risk to be smaller than the impact of risk as risk analysis may not equal risk accountability. Risk judgments can vary per the degree and type of uncertainty involved and the amount of information available at the time of decision making. Several definitions of risk exist in the literature, with a close link of them to formal probability theory. The commonest evaluation mechanism for one measure of project risk is to multiply its probability and its impact. The basis for evaluating the probability and the severity parameters of the concept often leads to varying risk definitions. Authors have often clashed on risk definitions. But this confusion may hinge on the common difficulty of distinguishing risk from uncertainty. For simplicity's sake, some evaluation mechanisms especially in the field of finance synonymize risk with uncertainty. But technically speaking, their meanings are different as uncertain situations involve unknowability while risky situations involve knowability (Fischer and Jordan 1996). Over the years, several questions have arisen from risk research. The key questions relate to what the natural unit of risk should be, and whether the uncertainty and severity components be multiplied directly in the sense that a small probability of a large loss is considered equivalent to a larger probability smaller loss.

Williams (1996) argues that proper consideration of project risk requires consideration of both impact and likelihood. Multiplying impact and uncertainty to 'rank' risks is misleading, since the correct treatment of the risks requires both dimensions. In dealing with a single risk, there is little danger in considering the multiplied figure. However, using the fundamental theory to combine or compare non-singular risk events can be erroneous. In trying to go round this problem, the idea of plotting such risks on probability-impact grids has gained popularity. However, rather than decreasing the dimensionality of the measure, some authors rather suggest an extension: Charette uses three-dimensional graphs with independent axes he labels severity (i.e. impact), frequency (i.e. likelihood) and 'predictability' (in technical terms, the extent to which the risk is aleatoric rather than epistemic). Wynne takes this distinction further, by distinguishing between risk (where the 'odds' are known), uncertainty (where the odds are not known, but the main parameters may be), ignorance (where we don't know what we don't know) and indeterminacy (described as 'causal chains or networks open' – so presumably implying an element of unknowability).

The variability of realized return around an expected value can be used as a quantitative description for risk (Fischer and Jordan 1996). In the finance literature, beta (β), has long been used as a statistical measure for unsystematic risk. Beta shows how the price of a security responds to market forces. As risk relates to profitability (Akintoye and MacLeod 1997), the capital asset pricing model (CAPM) provides a system for linking beta to the required return of a security or portfolio. Statistically, we can use the dispersion of realized return about an expected average as a quantitative description for risk (Fischer and Jordan 1996).

RESEARCH AIM AND OBJECTIVES

The aim is to ascertain risks affecting contractors in Ghana, and their impact on price. Specific objectives are: (1) to determine project risk levels experienced by contractors in Ghana; (2) to ascertain significant risks affecting contractors in Ghana; and (3) to ascertain impact of the risks on prices.

RESEARCH METHODOLOGY

To identify the significant risks affecting contractors in Ghana, and their impact on price, two potential strategies were identified thus:

1. Controlled experiment: where substantially complete building projects would be investigated using a before-and-after experiment and documentary analyses to directly identify project risks, and their respective impacts on prices.
2. Survey: where contractors would be asked using questionnaires to indicate risks they encountered on projects, and rank their significance.

Much of the empirical work on this has resulted from questionnaire surveys where researchers ask respondents to assign a ‘rank’ to risks listed from the literature. The significance of each risk is then made to correspond to relative importance indices calculated from the responses. Some examples in this include Liu and Ling (2005), Ghosh and Jintanapakanont (2003) and Fang *et al.* (2004). One can argue such measures of risk to constitute perceptions rather than direct measures of the risk.

To identify the significant risks in an underground rail project in Thailand, Ghosh and Jintanapakanont administered a questionnaire containing 59 variables (potential risk sub-factors) from a review of the literature in 17 previous studies. All 59 variables included in the questionnaire were set on a five-point scale – 5: extremely important, 4: very important, 3: important, 2: somewhat important, and 1: not important – and these scales were used to conduct factor analysis.

The questionnaires were sent to 150 respondents comprising project managers, managers, engineers, architects and project operation officers. In all, 122 respondents consisting of 10 project managers, 13 managers, 51 engineers, 5 architects and 43 project operation officers returned useable questionnaires. Factor analysis was the means of identifying the critical risk factors. According to importance indices, risk factors were ranked as follows: delay risk, financial and economic risk, subcontractor-related risk, contractual and legal risk, design risk, force majeure risk, safety and social risk, physical risk and operational risk. The client and project managers were also interviewed to obtain their assessment of the risk factors but it is not clear whether their assessment agreed with the ranking.

To model contractor’s mark-up estimation, it became necessary for Liu and Ling to identify the five most important factors affecting mark-up estimation, and to rate their degree of importance. The likely factors that influence mark-up were obtained from five past studies. From these studies, 52 attributes were uncovered and grouped into seven categories. The first part of the fieldwork sought to determine the most important and significant of these variables that affect mark-up estimation. A total of 142 survey packages were sent out on 1 September 2000. Responses were received between 5 September 2000 and 6 October 2000. Twenty-nine valid responses were received, giving a response rate of 20%. The primary section of the questionnaire was comprised of statements regarding the 52 attributes in seven main categories that may affect mark-up estimation, identified in the literature.

Respondents were asked to rank the main factors from 1 to 7. The 29 respondents provided different rankings and the Hungarian method was used to ascertain the overall rankings. Respondents were also asked to indicate the importance of these attributes on a five-point Likert scale, where 1 represented a response of ‘very unimportant’, 3 represented ‘moderate’, and 5 stood for ‘very important’.

The analysis helped to derive the relative importance of the seven factors. The most important attributes under the main categories were chosen to establish the model for mark-up estimation. Several other studies have used similar approaches to determine the ‘important’ risks. But this way of prioritizing risks is subject to the honest account of respondents, which may still have some distortions. Only positive risks that create losses were captured, and there is no indication of potential consequences in monetary terms.

Here, instead, we investigate direct measure of project risk by examining two measures of the same quantity, one ‘before’ and one ‘after’ construction of a project has taken place. Specifically in the context of contractors, the difference between ‘the expected return’ and ‘the realized return’ is the key measure (dependent variable) we examine through documentary analyses and interviews to identify project risks, and their respective impact on price. For the purposes of this study, we operationalize project risks as the factors (independent variables) responsible for the deviation of actual project outcome from the expected outcome. The impact of risk(s) on price will be quantified by using documentary analyses to investigate additional or reduced costs resulting from the risks.

The methodology was devised from the investigative approach used by Olken (2005) to investigate corruption levels in World Bank projects executed by local government officials in Indonesia. Using randomized controlled field experiments, he investigated missing expenditures in 608 village road projects in Indonesia. From the data on the financial reports, it was possible to calculate reported expenditures. From field surveys, it was possible for engineers to estimate the actual expenditures.

The dependent variable resulting from the difference between the two quantities on ‘what the villages claimed the road cost to build’, and ‘what the engineers estimated it to actually cost to build’, is the key measure of missing expenditure that was examined. The study controlled for some amount of normal loss during construction and measurement. Percent missing was also defined to be the difference between the log of the reported amounted and the log of the actual amount.

Most work in our field has focused on using questionnaire and interview surveys to obtain data on risks from respondents who may be clients, consultants or contractors. The annotations they assign are then resolved along the lines of relative importance indices to obtain the impact. A comparison between the proposed comprehensive experimental approach and the more common survey approach should reveal that for direct measures of risk and its impact on price, the experimental research approach is more appropriate for gaining a better understanding of risks and their impact on price.

RESEARCH DESIGN AND METHODS

To identify project risks and evaluate their impact on price, it became necessary to investigate the projects themselves and not the contractors as is commonly done by most researchers.

This work draws on a small literature to formulate an approach and measurement procedure for the investigation. In specific relation to construction, The Aqua Group (1999: 14) defines risk as the possible loss (or gain) resulting from the difference between what was anticipated and what finally happened. Shah (2001) explains that the risk concept is focused on deviation from expected outcomes. Fischer and Jordan (1996) define risk as the possibility that realized returns will be less than the returns that were expected. Based on these studies, it became logical to express the variability of return around an expected average as a quantitative description for project risk.

$$\textit{Risk} \approx \textit{realized return} - \textit{expected return} \qquad (1)$$

We can therefore quantify project risk in the context of contractors by examining two measures of the same quantity – return – one 'before' and one 'after' construction of a project has taken place. To do this, the difference between expected return (before) and actual return (after) on a project is the key measure (dependent variable) that will be examined. Project risks will be identified by investigating the forces causing deviation of actual values from the expected outcomes. The impact of each risk must show up somewhere in this difference between 'expected return' and 'actual return.' Since risk is the possibility that realized return will deviate from the expected return, we operationalize risk level as follows:

$$\textit{Risk level} \approx [(\textit{expected return} - \textit{realized return}) / \textit{expected return}] \times 100\% \qquad (2)$$

A resulting positive risk level may indicate not only the incidence of negative risks but also a greater net negative risk in some cases. The positive value may not necessarily mean the absence of some gains (positive risks) in some aspects of the project. Likewise, a resulting negative risk level may not exclusively connote the incidence of only positive risks but also a greater net positive risk in some cases. The conventions will reverse when base costs form the basis of measurement. We can thus estimate the impact of a risk event using the following relation:

$$\textit{Impact of a risk on price} \approx \frac{\textit{risk weight}}{\textit{expected price}} \times 100\% \qquad (3)$$

where: risk weight is the additional or reduced costs incurred from the occurrence of the risk event; and expected price is the price quoted by the contractor in the offer/bid.

Risk weight can be quantified by using documentary analysis to ascertain the extra or reduced costs of resources incurred from the occurrence of a risk event. This method can be supplemented by in-depth interviews to probe further. In future, we can simulate the data on each risk to ascertain whether it models a specific pattern, distribution or behaviour. Successful results can help to forecast the impact of a specific construction risk in Ghana on the price of a future project.

To control for measurement errors arising from differences in contractual capacity and varying project characteristics, only large public building projects constructed in Ghana by financial class D1 contractors were sampled. Financial class D1 contractors are the category of firms authorized by the Government of Ghana Ministry of Works and Housing to contract the largest projects because of their massive capital and resource outlay.

DATA COLLECTION

At the time of writing, data collection is still ongoing. This paper can therefore report the results obtained to date, and the plans for carrying out the rest of the work.

The data collection was done in three selected leading construction firms in Ghana, designated as sites for an ethnographic investigation into how contractors price risks.

Contractors were selected based on their suitability for the study and a willingness to allow a live study in their offices. Projects were sampled from the list of substantially complete building projects done by them in Ghana between 2000 and 2006. While obsolete data were considered undesirable, this time span was chosen to ensure a large enough sample and to help identify the impact of certain risks such as change in government and the country’s economic cycles on the performance of construction projects.

The main subjects of the study were quantity surveyors and site managers in charge of projects. Quantity surveyors usually have responsibility for cost-related issues on a project while site managers have insights into actual events encountered on the project during construction.

For each project, the inquiry started with a few general questions about the project to be investigated. This was followed with specific questions on: (1) expected return on the project (or the estimated costs to build); (2) actual return on the project (or the actual costs to build); (3) factors causing a difference between the two measures (risks); and (4) contribution of each factor to the overall deviation (risk weight).

The information may have been relatively more difficult to obtain using an ordinary research strategy. However, the ethnographic approach offered some advantage. The trust created between the researcher and subjects because of the relationships built allowed access to some classified documents and information.

It became necessary to involve the company accountants as it was realized that they possess a repertoire of cost information about projects. The accountants were helpful though not designated as original subjects for the study.

In some cases, it was difficult to obtain information relating to profitability directly. This was because of poor management practices and records keeping. It was difficult for the subjects to state the amount of return they expected from the projects. But after a project is complete, they find out the amount of profit made. They price the work, allow a safe margin for profit and overheads, and then wait until the project completes to find out the level of profit made.

The contractors rarely have a systematic mechanism for delineating a cost and profit plan against which they match actual project performance to ensure a required level of return. However, they all could tell what they expected a job to actually cost. Thus, in cases where subjects could not directly relate a required level of return, data on the ‘expected cost to build’ and the ‘actual cost to build’ were used to arrive at the same result. It became possible to approximate expected profit by applying the percentage they apportion to the base estimate for profit.

Thus, two alternative ways were used to obtain the data on profitability levels. One is a direct enquiry about expected and actual profit on a project; the second is an indirect enquiry that ascertains the expected and actual costs to build. The difference between the expected and actual return is the key measure examined to answer the research questions.

There was little control for the influence of geographic factors on performance. The nature of the study made it quite difficult to obtain a representative sample from all regions in the country. The dispersion of projects is satisfactory to permit some generalizations but the primary aim is a better understanding not representativeness.

On reflection, it was wondered whether more could realistically have been be done to control for geographic influences given the nature of the investigation. The data centre on profitability which most businesses feel quite secretive about. Besides, unlike very large countries like the USA which has four different time zones and 11 climatic regions, Ghana is a relatively small country with uniform time and weather where physical conditions do not vary much across the regions.

RESULTS

Tables 1–8 show results of risk experiments on eight building projects in Ghana.

Of the eight projects ranging between ¢850 million (Ghanaian Cedis) and ¢6.6 billion, two experienced a net negative risk while six experienced a net positive risk. In the context of this research, negative risk implies gain to a contractor while positive risk connotes a loss.

Contrary to a widespread view, there is no clear evidence that bigger projects experience higher levels of project risk. The range of impact on price is used to judge the significance of risks as follows: low significance (0–30%), medium significance (30–70%) and high significance (70–100%).

Table 1: Project no. 1 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 15% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
3 013 290	2 787 162	418 074	755 791	–337.72	–80.78	Appreciation in value of foreign currency	–310 203		–74.1981
						Late issuance of instructions from consultants		32 453	7.7625
						Old stock of materials	–845		–0.20212
						Variation claims	–76 303		–18.2511
						Extension of time		58 030	13.8803
						Defective work		12 305	2.9433
						Over measurement	–49 093		–11.7426
						Total risk	–436.44	102.79	–79.8078

Table 2: Project no. 2 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
6 480 000	5 325 000	532 500	467 312	65.19	12.24	Delay in arrival of expatriate subcontractor to install solar cells		64 040	12.0263
						Secured nature of site ensured minimal theft	Difficult to quantify		
						Inadequate design/spec.		24 000	4.50704
						Prompt/adv. payments	–12 345		–2.3183
						Mainly locally available materials specified, with little from offshore	–8690		–1.6319
						Total risk	–21.04	88.04	12.5831

Table 3: Project no. 3 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit - 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
1 500 000	1 300 000	130 000	69 105	60.90	46.84	Site topography was a problem		18 234	14.0262
						Inadequate design and specifications		15 435	11.8731
						Payment was very bad		32 000	24.61538
						Inflation	–33 098		–25.4600
						Materials wastage		13 000	10.0000
						Workforce strike		15 900	12.2308
						Total risk	–33.10	94.57	47.2854

Table 4: Project no. 4 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk-level (%)	Risk / opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
						Payment problems		45 050	8.7632
						Price fluctuation claims	–32 009		–6.2265

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000) Gain (–)	Loss (+)	Impact of risk on price (%)
						Extensive offshore material/problems with importation, etc.		52 240	10.16184
						Inadequate design/problems with subcontractors		13 457	2.6177
						Total risk	–32.01	135.75	20.1793

Table 5: Project no. 5 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
6 600 000	6 334 000	633 400	464 634	168.77	26.64	Many variations and conversions by client		33 988	5.3660
						Sectional completion to house residents while contract is in progress		54 004	8.5260
						Design was okay. It helped us to plan the job	Difficult to quantify		
						Payment delays		45 099	7.1201
						Materials wastage		23 567	3.7207
						Poor supervision		5005	0.7902
						Total risk	0.00	161.66	25.5231

Table 6: Project no. 6 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 15% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
3 006 208	2 974 458	446 169	987 896	–541.73	–121.42	Extensive incorporation of offshore materials		42 000	9.4135
						Excess. nom. subcontrs.		32 000	7.1722
						Price fluctuations	–88 976		–19.9422
						Site topography problems		23 430	5.25138
						Inflation	–232 527		–52.1164
						Foreign currency value	–359 071		–80.4788
						Poor coordination		12 900	2.8913
						Block plan problems		32 410	7.2641
						Total risk	–680.57	142.74	–120.5450

Table 7: Project no. 7 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	
805 905	771 681	77 168	60 550	16.62	21.53	Interference from user clients. Project was sponsored by the PTA		6222	8.0629
						Payment was very bad		40 098	51.9619
						Price fluctuation claims	–28 098		–36.41142
						Total risk	–28.10	46.32	23.6134

Table 8: Project no. 8 risks and their impact on price

Contract value (¢ 000)	Value of main contractor's work (¢ 000)	Expected profit – 10% of value (¢ 000)	Actual profit (¢ 000)	Risk (¢ 000)	Risk level (%)	Risk/opportunity events	Consequence (¢ 000)		Impact of risk on price (%)
							Gain (–)	Loss (+)	

4 301 928	3 857 272	385 727	467 932	–82.20	–21.31	Common use of facilities due to adjoining nature of projects	–52 234		–13.5417
						Materials stock	–44 435		–11.5198
						Bad weather		24 500	
						Payment was very bad		42 000	10.88852
						Site topography problems		–33 098	–8.5807
						Total risk	–96.67	33.40	–22.7536

DISCUSSION

Three out of eight projects experienced a net negative risk; more profit than expected was realized. These projects were observed to be of relatively medium size. The results in Tables 1–8 also show that the biggest risks contractors in Ghana face relate to inefficiency on the part of project consultants, payment problems and appointment of nominated subcontractors.

In-depth interviews accompanying the documentary analyses showed that many consultants in Ghana tend to fall short in their role as project team players. Working drawings generally carry mistakes and insufficient specification details. On projects, contractors may suffer from syndromes such as late issuance of constructional details and instructions from consultants. In addition, formal contract administration practices are not strictly the norm in most cases. Some of the shortcomings on the part of consultants may be attributable to some traditional cultural practices and norms that engulf Ghanaian society. Unfortunately, unproductive aspects of culture and mentality have filtered through into the construction process to inhibit productivity and delivery.

Poor adherence to time schedules is generally a problem in Ghana, procrastination is commonplace, suppliers and other service providers may commonly default in meeting delivery schedules. Some consultants would also expect ‘gestures of goodwill’ from contractors when they receive interim payments. The industry ought to take a serious view of this unprofessional and unethical practice in the interests of quality work and business survival. Payment delays is another risk which contractors in and entering Ghana ought to be mindful of when pricing. Clients of public projects consistently fail to honour interim payment within the contractually stipulated period of one month. Bureaucracy, insufficient project funds, a poor attitude towards work, and a need to contact almost everyone involved in the payment process (with an ‘incentive’) are the main drivers of this negative phenomenon. Sometimes, projects may stall for a while (when they are not abandoned) either because of a lack of funds or for political reasons. The appointment of nominated subcontractors usually takes a long time to happen on big projects. On site, their presence may sometimes delay the work if the chemistry with the main contractor is not appropriate.

In the years from 2001, the data show that some contractors who priced jobs before the change in government experienced windfalls on projects because of significant changes in Ghana’s macroeconomic position. Significant drops in the country’s inflation and foreign currency exchange rate meant that discerning contractors who included a price for the rising inflation and exchange rate of foreign currency in their bids started to make gains when economic policies of the new government started to lower inflation, interest rates and exchange rates significantly. We can see that in the absence of macroeconomic risks, contractors in Ghana incur an average risk of 26% in the execution of projects because of risks relating to consultants’ efficiency, delayed appointment of nominated subcontractors and payment problems.

Steps taken to deal with these risks can promote commerce and perhaps lower construction costs to clients. Problems relating to the extensive incorporation of offshore materials in designs and specifications are risks contractors also ought to consider due to import regulations. Other identified risks that relate to the management of internal resources include materials wastage, workforce strikes and poor supervision. Only three out of eight projects experienced profitability levels above what was expected. All other five projects ended up more costly than the bidders actually estimated. How then are contractors managing to cope and survive the effects of risks in the Ghanaian construction industry? Preliminary discussions with some contractors showed that they try to exploit opportunities during construction to balance losses.

CONCLUSIONS

An alternative rigorous method has been devised in this study to help identify the risks affecting contractors in Ghana, and their impact on prices. The study to date shows that consultants' inefficiency, payment problems and excessive delays in appointment of nominated subcontractors are the significant risks. Despite the heavy impact of these risks on prices, contractors are still able to cope because of their ability to exploit opportunities such as minimal enforcement of construction industry laws and regulations, stockpiling of resources, workers' due and entitlements, and inefficiency in the performance of consultants.

The investigative approach proved useful to the answering of research questions despite the belabouring amount of work involved. Poor record keeping and the sensitive nature of the data required were some of the challenges encountered. The primary concern has been for a better understanding of risks and their impact on prices, and not necessarily generalizations and representativeness. The results can help contractors in and entering Ghana to price risks into bids. Further research on the approach is recommended.

ACKNOWLDEGEMENTS

Mere thanks are inadequate to express the gratitude I owe to Professor Will Hughes of the School of Construction Management and Engineering at University of Reading for providing guidance to my PhD studies and for giving me the idea. I also need to thank Professor Edward Badu of the Department of Building Technology, KNUST, Kumasi and Dr Francis T. Oduro of the Department of Mathematics, KNUST, Kumasi.

REFERENCES

Akintoye, A S and MacLeod, J M (1997) Risk analysis and management in construction. *International Journal of Project Management*, **15**(1), 31–8.

Al-Bahar, J F and Crandall, K C (1990) Systematic risk management approach for construction projects. *ASCE* Journal *of Construction Engineering and Management*, **116**(3), 533–46.

Brun, W (1994) Risk perception: main issues, approaches and findings. *In*: G Wright and P Ayton (Eds.) *Subjective probability*. John Wiley & Sons.

Charette, R (1989) *Software engineering risk analysis and management*. McGraw-Hill.

Fang, D, Fong, P S and Li, M (2004). Risk assessment model of tendering for Chinese building projects. *ASCE Journal of Construction Engineering and Management*, **130**(6), 862–8.

Fischer, D and Jordan, R (1995) *Security analysis and portfolio management*. London: Prentice Hall.

Ghosh, S and Jintanapakanont, J (2004) Identifying and assessing the critical risk factors in an underground rail project in Thailand: a factor analysis approach. *International Journal of Project Management*, **22**, 633–43.

Liu, M and Ling, Y (2005) Modelling a contractor's markup estimation. *ASCE Journal of Construction Engineering and Management,* **131**(4), 391–9.

Neufville, R and King, D (1991) Risk and need for work premiums in contractor bidding. *ASCE Journal of Construction Engineering and Management*, **117**(4), 659–73.

Olken, B (2005) Monitoring corruption: evidence from a field experiment in Indonesia. NBER Working Paper 11753, November 2005.

Shah, S (2001) *Risk quantification in rapidly changing business environments*, available at www.irmi.com/Expert/Articles/2001/Shah01.

The Aqua Group (1999) *Tenders and contracts for building.* 3ed. London: Blackwell Science.

Williams, T M (1996) The two-dimensionality of project risk. *International Journal of Project Management*, **14**(3), 185–6.

Wynne, B (1992) Science and social responsibility. *In*: J Ansell and F Wharton (Eds.) *Risk: analysis, assessment and management*. Chichester, UK: Wiley.

CONSTRUCTION RISK MANAGEMENT AS A UNIVERSAL SYSTEMATIC APPLICATION

Peter J. Edwards[1] and Paul A. Bowen[2]

[1]*School of Property, Construction and Project Management, RMIT University, Melbourne, Australia*
[2]*Department of Construction Economics and Management, University of Cape Town, South Africa*

Risk is pervasive in that it is encountered in every aspect of construction projects and is experienced by every participant in the delivery process. Adopting a perspective of risk being associated with events with consequence that affect objectives, the application of risk management systematically across the management processes of construction is demonstrated. A central assumption is that a single project risk management system is neither possible nor desirable under most approaches to building procurement.

Keywords: project management, risk.

INTRODUCTION

Risk is universal. We are all exposed to it and we all have to deal with it. What differentiates risk is how each of us perceives it and responds to it (individually or organizationally). Since risk is a social construct, arising out of societies' world views and perceptions of risk events and their impacts, different people are likely to have differing views about what constitutes risk; the source of risk events; their consequences and preferred treatment. The paper explores, through the experiential learning of postgraduate students, how these differences can influence our understanding of risk management. It commences with a brief review of risk and risk management, and then follows the systematic processes of risk management as experienced in the learning activities of postgraduate project management students. The objective is to align project risk management theory with practice.

RISK AND RISK MANAGEMENT

Risk

Definitions of risk abound. Many are negatively framed as threats, defining risk in terms of the adverse consequences of risk events. Fewer definitions are positively framed, regarding risk as an opportunity giving rise to profit. A neutral perspective is provided by AS/NZS 4360 (2004) where risk is defined as: 'the chance of something happening that will have an impact on objectives'. This is appropriate in the context of construction projects, where the achievement of objectives is vigorously pursued by stakeholders. Understandably, project stakeholders still tend to hold a threat perspective of risks, since more importance is given to protecting the achievement of targeted outcomes than to windfall possibilities of exceeding them. The literature of construction risk management largely reflects this negatively skewed perspective. This is also understandable, since the techniques for managing threat and opportunity risks

[1] peter.edwards@rmit.edu.au

are not identical (Edwards and Bowen 2005). In this paper, a threat risk perspective is adopted for the sake of brevity. As Figure 1 shows, the time aspect of risk is also important, particularly in a project context.

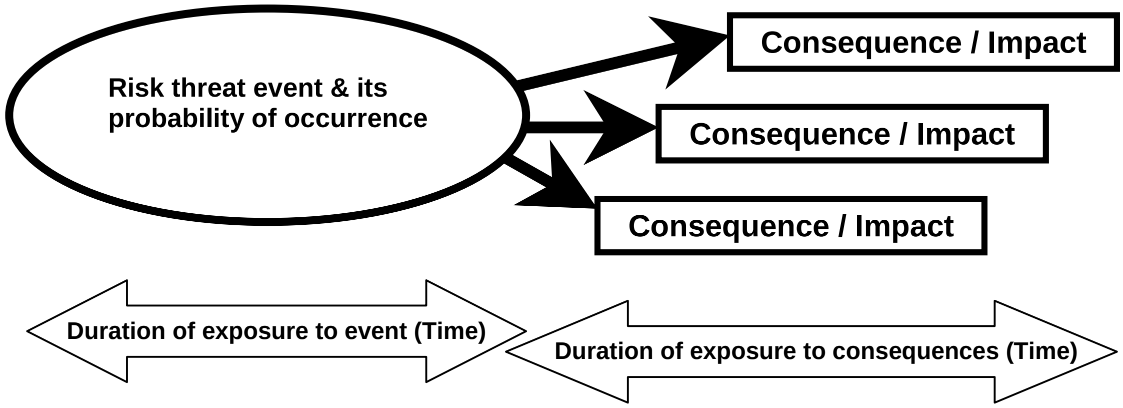


Figure 1: Components of risk

Risk management

Risk management is a systematic way of dealing with risk. While it is possible to treat risk reactively – after the risk event – it is sensible and prudent to consider risk events and their treatment *ex-ante*. The degree of risk preparedness to some extent reflects individual and organizational attitudes towards risk; i.e. risk perceptions and risk attitudes reside in people (and hence in organizations) and not in projects. Similarly, while an individual might adopt a relatively intuitive approach to dealing with risk, organizations (e.g. project stakeholders) need to be more systematic (and accountable) in their risk management.

Generic approaches to risk management are extensively offered in the literature (e.g. Flanagan and Norman 1993; Chicken 1994; Chapman and Ward 1997; AS/NZS 4360 2004; HB 436 2004; Edwards and Bowen 2005). While differing in detail, common processes of risk management emerge from these offerings. Systematic risk management should:

- establish the context;
- identify risks;
- analyse risks;
- respond to risks;
- monitor and control risks;
- capture risk knowledge.

The following section explores these processes in practice from a classroom perspective. The authors each have extensive experience of teaching risk management classes, at undergraduate and postgraduate level, at universities in Australia, South Africa and Singapore. Valuable knowledge derives from the tutorial and assignment learning experiences of postgraduate project management students when these are based upon the students' professional experiences. Many of the postgraduate students we have encountered have held quite senior positions in project management, across a variety of project types (including construction). Few have had extensive experience in systematic risk management. Fewer still have worked in organizations where formal risk management systems (RMS) are in place. The students' classroom involvement has yielded 'rich' information which is used here as comment and illustration about risk management as a universal systematic application, but with specific reference to construction projects.

ESTABLISHING THE CONTEXT FOR RISK MANAGEMENT

The obvious context for risk management is the unique construction project. However, since this is inevitably a large undertaking, it is usually found to be inadequate as a framework for risk management without careful amplification in some way. If a project is regarded from a systems perspective, it is useful as a means of distinguishing risk events occurring within the project system boundary from those occurring outside in other systems. For example, the economic risk of bottlenecks in the supply of materials or labour is extra-project in origin but intra-project in impact. On the other hand, an accident occurring on site is usually an intra-project event, with consequences likely to be both intra- and extra-project. Delineating the project system boundary was found to be a useful precursor to risk management by students.

Risks on projects arise from the decision making associated with the pursuit of project objectives (Parkin 1996). Client stakeholders may have procurement (acquiring the asset), functional (operating the asset) and strategic objectives for projects. While procurement objectives typically focus upon meeting time, cost and quality objectives, and functional objectives describe what the project is required to do, strategic objectives relate to what the client is trying to do with the project. An education department, for example, might build a new high school to improve the quality of educational facilities in a particular region; or a property investment company might develop a new shopping centre in order to change the risk profile of its asset portfolio.

Richards *et al.* (2005) have noted that, for some South African clients, mismatches may arise between desired procurement objectives and strategic objectives, but differences in inter-stakeholder procurement objectives for projects create greater problems. Project management students rapidly perceive that each stakeholder in a project could have objectives that differ from those of the client/sponsor. A contractor might accept the client's time, cost and quality procurement objectives for a project, but may have further objectives in not wanting to make a loss, in ensuring that any scope changes are reimbursed and in wanting to develop a client/contractor relationship that will positively influence the chance of obtaining future contracts. Since different stakeholders will have different objectives, and since for some stakeholders there will be conflict between objectives, the risks for each stakeholder will be different. The notion of a project risk management, as a single common system which each stakeholder can 'buy' into, is impracticable. Each stakeholder must manage its own risks, but its system for managing project risks must align with its own organizational risk system.

The nature of projects means that decisions are made, at a very early stage, which might affect the procurement of a project, its operational environment, and even its eventual disposal. Project management students with a background in construction projects sometimes find this concept difficult to follow through in terms of risk management. This is understandable, given their preoccupation with the procurement (project delivery) phase. Exposure to the needs of 'events' projects helps students to appreciate the operational and disposal phase risks of projects and a student having project management responsibility for the temporary construction work for the Australian Formula 1 Grand Prix event was able to demonstrate this. Held on a ‘street’ circuit in a public park in Melbourne, the complete event, with its supporting minor car races and official practices, takes place over one week. Twelve weeks is allowed for preparatory work on site, and the park has to be restored to its former condition within six weeks after the event. Thus all three environments – construction, operations and remediation – are experienced in just over four months. Students from the telecommunications industry found even 19 weeks a comparatively long project period. For them, projects involving new services were generally allowed no more than six weeks from inception to delivery of the product to market, in order to maintain competitive advantage.

Establishing the context for project risk management entails:

- nominating the stakeholder whose risks are to be managed;
- identifying the dominant organizational aspect of the stakeholder where project decisions are made;
- identifying the target project;
- clarifying the stakeholder’s project objectives;
- selecting the relevant project environment(s) – procurement; operation; disposal.

Knowing the context allows risk identification to proceed.

RISK IDENTIFICATION

For the most part, whether working individually or in syndicate groups, students use simple brainstorming to identify project threat risks, guided only by their understanding of the project context. This approach, however, itself poses the risk that some threats to the achievement of project objectives might go undetected. Certainly brainstorming is necessary, since no automated risk identification exists and each project is unique, but undetected risks represent real threats to projects since they cannot be managed proactively and preclude the planned exploitation of possible opportunities. For more comprehensive risk identification, students found that they needed to use brainstorming within a more structured risk identification technique.

Existing techniques of risk identification can be found in the literature, but not all are appropriate in the context of construction projects. HAZOPS (Hazard and Operability Studies) and FECMA (Failure Effects and Criticality Mode Analysis) are intended for the chemical engineering and automotive manufacturing industries respectively (AS/NZS 3931 1998) but are more suitable for application to the operational environments of those facilities rather than to their procurement (construction phase). Sutton (1992) explains event tree analysis (ETA) and fault tree analysis (FTA) as risk identification tools, but their real benefit lies more in the analytical phase of risk management. Checklists are advocated (Chong and Brown 2000) but are constrained by their reliance on the availability of information from similar historical projects.

Aids to risk identification can be regarded in terms of their primary focus, which may be verbal, numerical or graphic. Techniques with a verbal focus (qualitative relationships) include checklists, methods statements, work breakdown structures, flow charts, mind mapping, concept mapping, situation awareness (McLucas 2003) and HAZOPS. Some of these have a graphic element, but the focus is usually on the text labels that are generated. Numerically focused techniques (quantitative relationships) include scheduling, critical path analysis, FECMA, ETA and FTA. Tools with a graphic focus (visual relationships) include scenarios, rich pictures and storyboarding. The latter is a newcomer to project risk management, and largely untried but it promises to be an effective technique.

The purpose of all these techniques is to expose risks (mainly threats but also opportunities) through identifying areas of relative uncertainty in the project.

A clue to more effective risk identification lies in expanding the project context. Since establishing the context involves describing the project and its objectives, a logical question then to ask is how these are to be achieved?

The constituents of all projects are tasks (what is to be done), technologies (how it is to be done), resources (what is needed to undertake it) and organization (the framework within which decisions are made and everything is planned and managed). Devices such as method statements, work breakdown structures, activity networks and resource schedules are useful as tools to guide risk identification brainstorming, particularly when focused upon the decision making associated with them (Edwards and Bowen 2005). The risk identification questions then centre on what could threaten a successful outcome for this task, the application of this technology, the acquisition of this resource or the effective management of all of these?

Students find this decomposition approach to risk identification useful but time-consuming, and point out that the level of project decomposition is limited by the extent of project information available. To some extent, this is a circular argument, since ‘unknown’ projects are inherently more risky than ‘known’ projects (Smith 1999), but unless some attempt is made to explain the unknowns – and expose their assumptions – their risks will not be identified.

Despite encouragement to be precise, project management students tend to use only one or two words to describe the risks they have identified. ‘Cost overrun’ is a favourite term, despite the fact that it is actually the consequence of a prior risk event. More precise risk statements are necessary for effective communication among the project team, and are often useful in pointing towards appropriate risk response treatments. The importance of effective communication has been emphasized by Edwards and Bowen (2005). A precise risk statement ideally includes references to the type of risk, the risk event and its likelihood, and the consequences for the project, plus an indication of the exposure period where appropriate. An example of a contractor’s construction project risk statement might be:

> There is a chance that shortages in the supply of cement will occur over the next 12 months, causing delay and additional cost during the concrete casting phase of the project (economic risk).

This level of precision provides a clear framework for subsequent analysis and assessment of risk severity.

RISK ANALYSIS

Because of the inherent association of uncertainty with risk, some authors (e.g. Grey 1995) place a heavy emphasis on the treatment of uncertainty in risk analysis, focusing upon techniques such as Monte Carlo simulation as a modelling engine. While not eliminating uncertainty – only more and improved information can do that

– such techniques allow decision making to proceed on a more mathematically precise basis.

Few postgraduate project management students were found to have more than a superficial understanding of mathematical treatments of uncertainty. Most were unconvinced of any real need for them, and some students even suggested that, from their own project experience, detailed assessment of risks was rarely needed and that their professional judgement was enough to determine whether or not treatment was required. Many thought that a quick assessment of the relative severity of each identified risk would suffice, as this would allow them to prioritize the allocation of risk treatment resources. Students accepted that this approach would entail qualitative assessments of likelihood of occurrence (probability) and impact for each risk along the lines postulated in the guide to AS/NZS 4360 (HB 4360 2004) where five-point Likert scales are suggested. Scale intervals for probability start at *rare* for the lowest probability and proceed through *unlikely, possible,* and *likely* to *almost certain*. For threat risks, the impact scale ranges from *insignificant*, through *minor*, *moderate* and *major* to *catastrophic*. Scoring the intervals from 1 to 5 allows the product of probability and impact to represent the severity of each risk to be rated from 1 to 25. This two-dimensional assessment process can be expanded by adding a third dimension to represent duration of exposure (allowing a 1–125 severity scale, but most students thought that this would not be necessary for the types of projects they tended to undertake. Alternatively, the two-dimensional scales could each be simplified to three points: *low, medium* or *high*, giving a 1–9 severity range. Despite its greater simplicity, students did not favour this option on the grounds that it did not provide sufficient discrimination in the risk severity assessment. They suggested that very severe risks could always be subjected to more extensive mathematical analysis.

While asserting that a qualitative assessment approach to establishing relative risk severity was sufficient for their risk management needs, students were far less appreciative of the consequent need to define the scale intervals for this technique. They tended to rely on an invalid assumption that the given intervals conveyed a universal linguistic meaning that would be easily communicated and understood by everyone involved. When it was pointed out that the criteria for *unlikely* and *catastrophic*, for example, might hold different interpretations for different stakeholders, the uniquely personal/organizational perceptions of risk became much clearer to the students. They also appreciated how establishing these interpretations might be a valuable exercise in strategic risk management for their organizations, reinforcing the desirability of aligning risk assessment criteria to strategic (business) objectives.

Students found further benefits in qualitative risk analysis through the risk mapping opportunities that this presented. Two-dimensional matrices, with risk categories across the top row and work breakdown (or similar) stages down the vertical column, and with the cells populated with the identified risks, could reveal clusters of risks of particular types or for particular activities. A refinement to this approach incorporates project risk complexity mapping (Edwards *et al*. 2005) using the definitional approach to complexity suggested by Williams (1999).

RISK RESPONSE

Postgraduate project management students generally found the risk response process to be the most creative part of risk management, often coming forward with innovative ideas for avoiding, transferring or reducing risks. They were not content to simply retain risks without some attempt at mitigation, but recognized that in practice retention was sometimes the most cost-effective treatment. Students found that often their project stakeholder organizations had existing treatment procedures already in place for at least some of the identified risks. They then needed to identify and bridge any gaps. The students experienced the iterative nature of systematic risk management, since most risk reduction options require a re-analysis of residual risk severity, and risk avoidance or transfer measures may introduce new risks that must be identified and treated.

The most important learning for students in this phase of risk management was about possible targets for risk response treatments. They found that addressing the probability component of risks usually involved trying to reduce the likelihood of occurrence of a risk event by doing things better (e.g. quality management) or more safely (safety management), by enhancing or increasing the frequency of management interventions and inspections, or by raising reporting requirements for monitoring. Reducing the impact (consequences) of risk events was often a matter of providing extra resources, back-up facilities, or planning the deployment of emergency procedures, while risk exposure duration could sometimes be addressed through rescheduling or introducing more scheduling flexibility.

RISK MONITORING AND CONTROL

Since risks are usually dynamic (i.e. the probability and/or impact can change over time), it makes sense to monitor and control them once risk response decisions have been made and treatments implemented. Most students regarded this risk management activity as simply planned extensions to control measures already in place on their projects. Many thought that reporting procedures might become more onerous, but suggested that this would not be an unwelcome development, particularly in the light of modern demands for corporate responsibility and accountability. They regarded this as an important aspect of risk knowledge capture.

CAPTURING RISK KNOWLEDGE

Apart from the knowledge captured during the monitoring and control phase of project risk management, students saw value in post-project gathering of risk information. Many postgraduate project management students indicated that post-project debriefing occurred in their organizations, but nearly all suggested that this was rarely done from a risk perspective, since their organization had no formal risk management system in place. Students offered several ideas for value-adding to this activity. One reported that project risks were recorded in his organization in a ‘project risk schedule’, and that post-project risk knowledge was entered into an organization-wide ‘risk register’. Another noted that, besides risk knowledge captured from its own projects, her company gathered risk information from other sources (newspaper and magazine articles, journal papers, even television programmes). In addition to applying this knowledge on future projects, it was sometimes adapted for use as staff training material within the company. A student from the telecommunications industry stated that his organization periodically analysed information from its risk database to look for risk trends in its projects.

These ideas indicate that, not only were the organizations involved displaying a high level of risk management maturity, but also that their risk management systems were not being allowed to become simply passive repositories of risk information and knowledge.

CONCLUSIONS

Students, especially at postgraduate level, are a rich source of risk and risk management knowledge. Pooling their wisdom adds considerably to the body of practical knowledge about risk management.

In their class participation and assignments, students displayed appropriate abilities in some aspects of systematic risk management, but weaknesses in others. They were able to establish clear project contexts but, despite acknowledging the criticality of risk identification, showed an over-reliance on unstructured brainstorming to identify risks. Qualitative risk analysis was heavily preferred over quantitative techniques, unless the latter were actually required in the project design process or used for specific financial appraisal of projects. However, unwarranted assumptions were made about organizational interpretation, communication and understanding of qualitative risk assessment scale intervals. Risk mapping was thought to be a useful technique, especially for inter-project comparisons. In the risk response phase, the opportunity for creatively exploring risk treatments was appreciated. For risk monitoring and control, students generally found themselves on more familiar ground whereby existing project control procedures already flagged or monitored risks to some extent, or could be adapted to do so. The capture of project risk knowledge was seen as a somewhat neglected activity, but acknowledged as important for organizations involved in projects, not only for its applicability to future projects but also for the potential it gave for developing competitive advantage.

It was noticeable was that, in almost every project stakeholder organization where the students' stories suggested the presence of a high level of risk management maturity, a 'champion' for systematic risk management was also evident – usually a director or senior manager.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the participatory contributions of students from Master of Project Management courses at RMIT University and the University of Cape Town.

REFERENCES

AS/NZS 3931 (1998) *Risk analysis of technological systems – application guide*. Homebush, NSW: Standards Australia.

AS/NZS 4360 (2004) *Risk management*. Homebush, NSW: Standards Australia.

Chapman, C B and Ward, S C (1997) *Project risk management: processes, techniques and insights.* Chichester: John Wiley and Sons.

Chicken, J (1994) *Managing risks and decisions in major projects*. London: Chapman and Hall.

Chong Y Y and Brown, E M (2000) *Managing project risk.* London: Pearson Education Ltd (Prentice Hall).

Cooper, D F (2005) *Project risk management guidelines: managing risk in large projects and complex procurements*. Chichester: John Wiley and Sons.

Edwards, P J and Bowen, P A (2005) *Risk management in project organisations*. Sydney: UNSW Press; London: Elsevier Science International.

Edwards, P J, Hardcastle, C and Bowen, P A (2005) Mapping risk and complexity for construction projects. Paper presented at *Becon2005* – 1st International Conference on Built Environment Complexity, 11–14 September, Centre for Complexity Research. University of Liverpool, UK.

Flanagan, R and Norman, G (1993) *Risk management and construction*. London: Blackwell Science Publications.

Grey, S J (1995) *Practical risk assessment for project management*. Chichester: John Wiley and Sons.

HB 436 (2004) *Risk management guidelines companion to AS/NZS 4360*. Homebush, NSW: Standards Australia.

McLucas, A C (2003) *Decision making: risk management, systems thinking and situation awareness*. Canberra: Argos Press.

Parkin, J (1996) *Management decisions for engineers*. London: Thomas Telford.

Richards, P, Bowen, P, Root, D and Akintoye, A (2005) Client strategic objectives: the impact of choice of construction contract on project delivery. *Construction Law Journal*, **21**(7), 473–92.

Smith, N J (1999) *Managing risk in construction projects*. London: Blackwell Science Publications.

Sutton, I S (1992) *Process reliability and risk management*. New York: Van Nostrand Reinhold.

Williams, T M (1999) The need for new paradigms for complex projects. *International Journal of Project Management*, **17**(5), 269–73.

THE APPLICATION OF INFORMATION TECHNOLOGY TO SUPPORT THE ELICITATION OF EXPERT JUDGEMENT IN PROJECT RISK MANAGEMENT

Alan D. Russell[1] and Cheryl E. Nelms

Department of Civil Engineering, University of British Columbia, 6250 Applied Science Lane, Vancouver, BC, V6T 1Z4, Canada

Of the various steps that comprise risk management, difficulties are still encountered in identifying risk events as a function of project context and project participant viewpoint, and eliciting the properties of these events. Described is an IT based approach that is especially suited for application on large infrastructure projects and which has been designed to assist with the elicitation of expert knowledge pertaining to risk drivers and associated risk events, likelihood of occurrence of the risk events identified and outcomes expressed in terms of several measures, including time, cost, quality and security. Central to the approach is the concept of profiling components of a multidimensional representation of a project in terms of attributes and their values, subsets of which in turn singly or in combination act as drivers of risk events and their properties. The approach adopted also builds on the work of others as well as the practical experience of the authors gained through the participation in risk identification and expert opinion elicitation sessions. Elaborated upon is how such an approach may be operationalized using computer-based methodologies that include knowledge management, visualization, and an integrated multi-view representation of a project which reflects its physical, process, environmental and organizational/contractual dimensions. Use is made of a case study to illustrate aspects of the approach.

Keywords: information technology, project management, risk, visualization.

INTRODUCTION

In this paper, we introduce aspects of a methodology incorporated in a project management software tool for the management and reuse of risk knowledge and related information. Emphasis is placed on a concept of profiling that is applicable to both the identification of risks and elicitation of their properties using expert opinion, and how it has been realized in an information technology (IT) environment. Motivation for the work has come in part from the increasing trend by governments worldwide to adopt alternative procurement approaches to meet infrastructure needs and achieve greater transfer to the private sector of the project scope, time, quality and cost uncertainty that is inherent in infrastructure projects. This in turn has led to more emphasis being placed on risk management in the early phases of a project to ensure government accountability and value for money. A number of commercially available software tools exist to support the project risk management process including RiskEasy® (NOWECO 2006), Risk Radar® (ICE 2006), PertMaster Project Risk

[1] adr@civil.ubc.ca

(PertMaster 2006) and RiskCom (see Hall *et al*. 2001). While very useful for the tasks for which they were designed, a number of shortcomings exist with these tools. These include the inability to connect or integrate risk issues with the project context, a disconnect between risk management and other project management processes, little if any exploitation of knowledge management concepts, limited support for different cognitive styles for both identification and elicitation tasks, and treatment of only a subset of risk event outcomes. These deficiencies combined with the need for further improvement in the state of the art of existing identification and elicitation techniques and our own experience in assisting with the development of risk profiles for infrastructure projects have provided the impetus for the work described herein.

The processes of risk identification and elicitation may be defined as identifying perceived issues or concerns and determining their characteristics or properties. Tools commonly used for risk identification include checklists, brainstorming, interviews, historical documentation reviews, cause/effect and influence diagramming techniques and expert judgement. Expert opinion elicitation is a term used to describe a process of gathering information and quantitative or qualitative estimates that can support the risk identification process. That is, and as expressed in relatively general terms, one seeks to *identify* X (the risk event) which occurs at location Y because of the presence of drivers $\{Z_1, .. Z_n\}$in the form of components and their attribute values at location Y, and *elicit* the properties including likelihood P of event X occurring (expressed quantitatively or qualitatively), the performance criteria $\{C_1, \ldots, C_m\}$ impacted and criteria outcomes $\{O_1, \ldots O_m\}$, expressed quantitatively or qualitatively or a combination of the two. Although not addressed directly in this paper, to assist with the *elicit* part of the foregoing, there is a rich literature on expert opinion elicitation techniques applicable to the field of engineering, approaches for combining expert opinions and cognitive heuristics and biases of which facilitators and participants of risk identification and expert opinion elicitation sessions must be aware (e.g. Morgan and Henrion 1990; Cooke 1991; Ayyub 2001).

Integrating the tasks associated with risk management with those associated with the overall project management process and incorporating knowledge management techniques in support of these tasks poses a significant challenge, which must be addressed if better quality risk identification and quantification is to be achieved. The importance of establishing context to assist with the risk management process is a concept adopted in the AS/NZS 4360 Risk Management Standards and highlighted in the *Enterprise risk management guidelines* (Government of British Columbia 2006), a framework for performing risk management for public sector projects in the Province of British Columbia, Canada. Also, Akintoye *et al.* 2003 summarize the results of an investigation of risk management in private finance initiative (analogous to an alternative financing mechanism) projects which highlighted that incomprehensive upfront project information, poor historic statistical risk data, and lack of risk information from previous projects in the form of a risk library adversely affected the ability to meet value for money requirements of the government sector.

The objective of this paper is to introduce features of an approach and supporting tool that concurrently improve upon current risk identification processes and expert opinion elicitation tasks. The multi-view representation of a project in terms of hierarchical structures of components, combined with the ability to profile components in terms of user and in some cases system-generated attributes and make associations among components of the various views, facilitates an integrated approach to the tasks of risk identification and elicitation. The tool provides a standardized platform in which risk terminology is made explicit. In our approach, a risk is defined as the potential variability in a project parameter from its anticipated value (e.g. higher than expected inflation rate during the construction phase which is described in terms of a density function for the inflation rate), or as a discrete risk event (e.g. contaminated soil encountered) which can be described in terms of different state values realized, likelihood of occurrence of each state, and vector of outcomes, given the realization of a specific state of occurrence. The primary focus here is on discrete risk events as opposed to assessing variability in estimates of basic variables, and within this focus, attention is directed mainly to the identification of risk events with lesser emphasis on the elicitation of risk event properties. The remainder of the paper is organized as follows. Provided first is an overview of several questions that have guided the research, and a brief description of how each question either has been or is being addressed. Next is a description of a case study scenario that reflects an amalgam of the characteristics of projects with which the authors have had some involvement. This case study is then used as a background to highlight specific aspects of our approach to risk identification and elicitation. The paper concludes with a brief discussion of ongoing work and creation of a computer-based environment to facilitate interactive risk identification and elicitation sessions.

RESEARCH QUESTIONS

A number of intellectual and practical challenges arise in developing a computer-based methodology that can be used to integrate risk information with representations of the project context. As part of the underpinnings of our current approach, De Zoysa (2006) posed several questions to guide the initial development of the tool, three of which are of direct relevance to this paper. They are:

1. How should the relationship between project context and project risks be represented and how should the project context be modelled?
2. How should representations of project risks and their relationship with project context be exploited to gain insights for decision making, and in support of this, what querying, reporting and visualization functions are of use?
3. What knowledge can be reused for future projects; how can it be archived in a project neutral format; how should it be extracted from archives; and what assistance can be given in deciding the appropriate content to reuse?

Arising from these questions, and aided by previous work (Russell and Udaipurwala 2004), a multi-view representation of a project was enhanced and extended to treat the environmental (natural and man-made) and risk views of a project (Wang 2005; De Zoysa 2006). Using the notion of risk drivers, associations can be made between view components and a grouping of like risks, called a risk issue, and individual risk events can then be defined corresponding to the existence of one or more risk drivers at a particular project location or at a particular point in time. In support of this, a knowledge management component was developed which allows for a cataloguing of lessons learned from past projects in terms of how best to represent each of the product, process, organizational/contractual, environmental and risk views. Some exploration was made of how much of the process could be automated, which led to careful consideration of the most appropriate roles of the machine versus human risk expert. Finally it was determined that much work remained to be done with respect to question (2), especially in regard to visualization in real time of any clustering of risk events in time, space and by organization, which potentially has a direct impact on values sought as part of the elicitation task.

Building on De Zoysa's work, in addition to more work being required on questions (1) and (2), further questions as follows have been posed to improve the application of the tool with respect to identification and elicitation of risks and their properties:

4. How should the groupings of risks in the temporal, spatial and project participant context and their potential interactions be treated?
5. How should the cognitive styles and value systems of the multiplicity of participants involved be accommodated in order to ensure that the full spectrum of risk events is identified and the full dimensionality of their consequences treated should they occur?
6. What features are required for the design of an interactive man–machine interface to be effective for group risk identification/elicitation sessions in support of questions (4) and (5)?
7. How should the evolution of risk information and outcomes over the project life cycle be accommodated?

As described in the following section, current work is directed at question (1) using the concept of profiling, and its relationship with question (3). Other current work is directed at the use of visualization to provide feedback on the clustering of risk events and related drivers in one or more of the spatial, temporal or organizational dimensions of a project. This is of direct assistance in terms of both identification and elicitation of risk event likelihood and outcome values. How to accommodate and calibrate different cognitive styles is of ongoing concern, with emphasis being placed on treating both quantitative and qualitative estimation approaches, including hybrid approaches. As research findings are implemented in an IT environment, careful attention is being devoted to interface design, a topic of considerable practical significance, with emphasis on improving group interaction and calibration, creating a shared understanding of project context among participants, speedy navigation of the project context and risk register, and ready feedback of available project information in a number of formats, especially visual ones.

CASE STUDY PROJECT

An elevated guideway expansion case study project, combining aspects of projects with which the authors have been involved, procured using a design–build–finance (DBF) procurement mode is used as a backdrop to illustrate our approach along with implementation details for identifying risks and eliciting their properties for purposes of risk management and other project management functions. The project consists of a 7.5km-long expansion to an existing elevated rapid transit system to connect Municipalities A and B and involves the construction of an elevated guideway structure, a bridge and four transit stations exclusive of any rail or rolling stock along a predetermined route. The construction estimate is Cdn$142.5 million (in constant dollars as of 31 March 2007) excluding costs associated with design, client oversight, client advisers, etc. The construction industry is currently at and beyond capacity in which selected trades and seasoned project management personnel shortages exist, and this situation is forecast to continue for the next two to four years.

Section 1 (3.04km) and Section 4 (1.52km) involves the construction of the new guideway built on a boulevard that runs down the middle of a main thoroughfare of

Municipalities A and B. Section 2 (0.55km) consists of the construction of three components including a transition (0.4km) from the elevated guideway to a bridge (0.065km) spanning a river and an elevated guideway commencing on the south shore of the river crossing the boundaries of a historic First Nations settlement and commercial railway track. Section 3 (2.39km) involves the construction of an elevated guideway across some light industrial and agricultural use land in the jurisdiction of Municipality B.

Risk issues in Sections 1 and 4 relate to concerns of a multiplicity of stakeholders lining the corridors (commercial, residential and business) that traffic flow and local business operations are not impeded during construction. A further concern is the substantial massing of overhead and underground utilities along the construction corridor in these Sections, the location of some of which is uncertain. Key undisclosed environmental and archaeological risks in Section 2 are the demolition of existing buildings on privately held land that may also require soil contamination abatement, environmental sensitivities and regulations where the bridge crosses a river and the existence of a historic First Nation settlement along the river shore. Stakeholder risks also exist in Section 2 where the bridge crosses a river, regulated by a multiplicity of governing authorities, used for both commercial and recreational activities and constraints imposed by a commercial rail company operating along the shore. Primary risks identified for Section 3 have been transferred to Municipality B, which has taken responsibility in securing easements for the elevated guideway across the light industrial and agricultural lands.

In summary, private sector consortia interested in the project face the challenge of identifying and quantifying potential technical, environmental, financial, participant and regulatory risks, some of which are interrelated, and determining relevant risk mitigation strategies as part of their decision as to whether or not to bid, and if yes, how to price out the risks.

APPROACH FEATURES AND IMPLEMENTATION DETAILS

Use is made of the case study to highlight features of our approach and accompanying risk management tool. Addressed, with emphasis on the second item are: (1) modelling of the project context using an integrated multi-view representation of a project; (2) profiling project view components in terms of attributes related to risk (i.e. risk drivers) and other project management functions; (3) developing a risk view (risk register and associated properties); and (4) knowledge management. These features are designed to contribute to improved decision making and risk management processes in both the project planning and execution stages relative to current standard industry best practices. Risk registers, developed by practitioners involved in infrastructure delivery and considered to conform to the current best practice approach to risk management in Canada, were used as the base reference documents to assess some of the benefits and limitations of applying the tool to model the project risks.

Integrated multi-view representation of a project
The project context is characterized through four different views: physical (what will be built and where), process (how it will be built and operated), organizational/contractual (the participants involved), and environmental (the natural and man-made environments in which it is being built). (A cost view has yet to be fully integrated with these views.) Consistency of representation has been sought for all views in the form of hierarchical modelling, with the granularity of each view

representation left to the user depending on the amount of information available and decision making required. The ability to make associations among the views is supported, including the ability to link them with the risk view by way of risk drive–risk issue associations. The physical view (not shown) treats the modelling of a project in terms of physical locations as well as physical components, with a mapping between the two. The same set of locations provides the underpinning for the process and environmental views of the project. Shown in Figures 1(a) and 1(b), respectively, are two of the hierarchical structures used to model the case study project. Each component in the hierarchy can be described in terms of a number of datasets as well as associations with entities from other views (for the latter, see the risk issues/events tabs in Figures 1(c) and 1(d)). As an example of the former for the environmental view, a geotechnical profile of the entity ‘contaminated soil’ can be described using the attributes and values tabs, with values assigned on a location-by-location basis. The integration of views allows for changes in the project context such as regulatory and scope changes to be reflected throughout the other views, including the risk view.

Profiling risk drivers

Thoughtful definition of the components and associated attributes used to represent the various views of a project can provide valuable insight to project managers and improve the overall risk management process. We have found that profiling of the different views in terms of user-specified attributes and anticipated values can be particularly useful in the elicitation of risk sessions. These sessions typically involve project participants from a range of disciplines who identify and manage risks from their own experience and knowledge domain. Few, if any, have a complete understanding of the full project context or spectrum of project risks. A multi-view representation of the project context can be used to guide or structure these sessions, help develop a common understanding among session participants, and serve as a mnemonic device to trigger the identification of potential risk events, interrelationships and mitigation strategies. Our focus on profiling here relates to defining the attributes required to characterize the constructs used for representing the various views of a project. These attributes can be described by way of a 2 × 2 matrix dealing with user vs. system-defined attributes (e.g. different attribute sets for different classes of project participant vs. schedule dates for activities), and user-specified vs. system-derived attribute values. Because of space constraints, discussion is limited to profiling for the organizational/contractual and environmental views of a project, and only touches on the use of attributes from the process view.

While implicitly the concept of profiling is not new to the construction industry literature, it could benefit from more explicit or formal treatment if management and decision-making practices are to be improved, particularly in terms of the breadth of issues that affect a project. In simple terms, profiling addresses the question: What do I really need to know about the project in order to perform the task at hand?

Profiling project stakeholders, a class of project participants, using techniques such as stakeholder mapping has been discussed in the construction literature as a means for project managers to identify stakeholders, their level of influence on the project and for improving risk and communication management. Newcombe (2003) discusses the importance of identifying project stakeholders and using stakeholder analysis or mapping techniques to analyse their power, predictability and interest to gain a better understanding of their expectations and impact on the project. Olander and Landin (2005) illustrate using stakeholder mapping on two case study projects and showed how the relevant stakeholders and the power and interest of these stakeholders changed over the course of the project and how this information may be relevant to the risk management process. Another example of profiling involves the work of Ling (2003), which deals with the selection of architects.

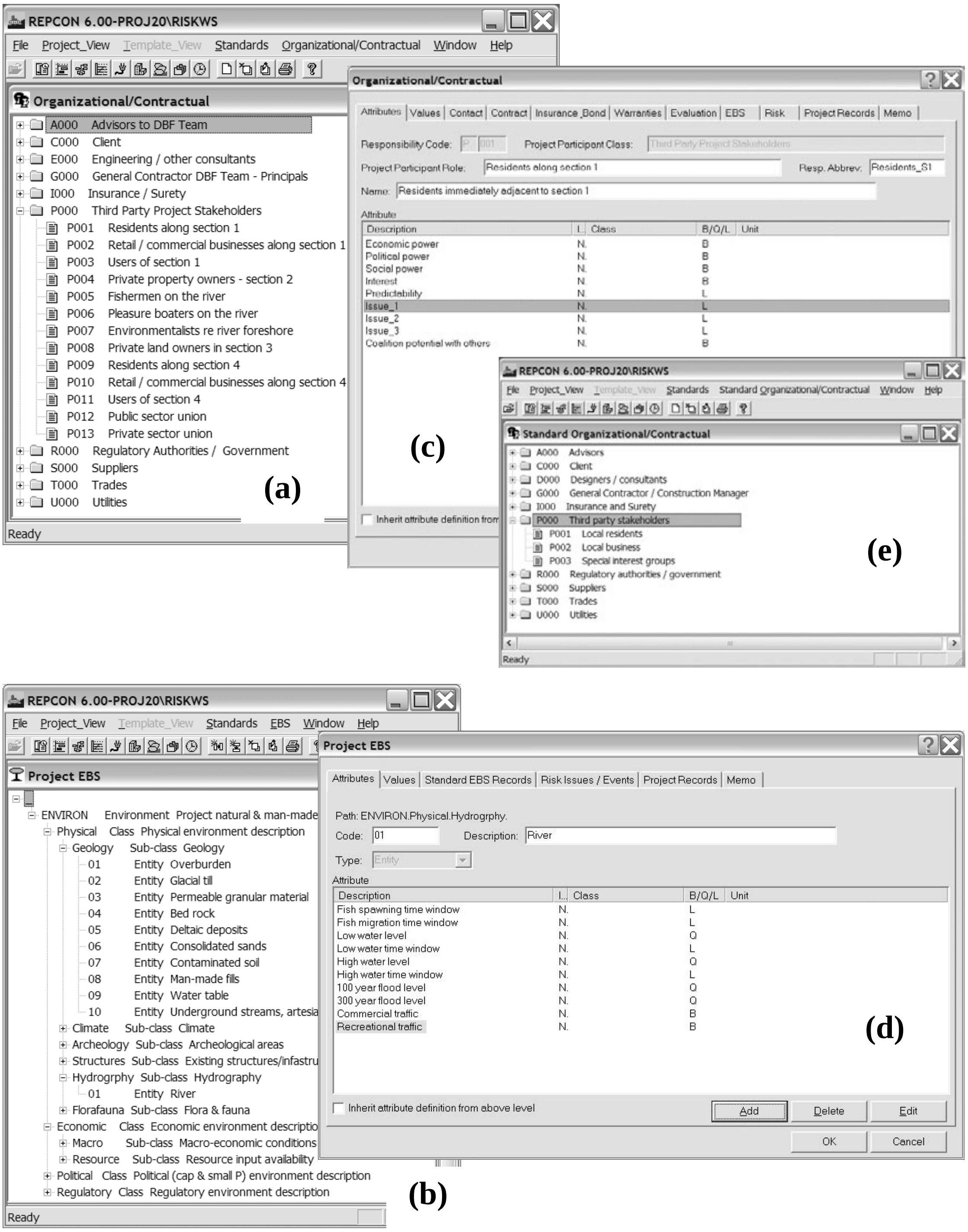


Figure 1: Representing the project context: (a) & (b) Hierarchical representation of the organizational/contractual and environmental views; (c) & (d) Profiling components of the respective views; (e) Knowledge management feature on system Standards Side

Shown in Figure 1(c) is profiling of one member of the third party project stakeholder class of project participants (Figure 1(a)), in this case residents along Section 1 of the case study project. Note the ability to define quantitative (Q), linguistic (L) and

Boolean (B) attributes, and to use inheritance to speed the definition of attributes at the individual member level of a participant class. Both expected value and actual value fields accompany the definition of attributes for the various views of a project. Profiling project stakeholders assists with the identification of risk events, drivers and even risk mitigation decisions such as the level of resources a project manager should assign to stakeholder management, as well as with other functions such as communication. Using the attributes cited and their respective values, the project manager can gain a better understanding of stakeholder dynamics or identify risk events and mitigation measures when considering such issues as anticipating how construction method decisions will affect this stakeholder group. Shown in Figure 1(d) is a profiling of the entity ‘river’ within the class-subclass-entity hierarchy of the environmental view (Figure 1(b)). Of particular interest for the case study project are attributes related to fish and water levels. These attributes may have a positive, negative or no project impact such that some are risk drivers and others are not depending on design features (the physical view), regulatory constraints (part of the environmental view) and construction methods used and timing (system derived attribute values) of related activities (the process view). The power of modelling and profiling project components and their attributes in the four views enables the user to link risk entities to the associated component and determine the temporal and spatial distribution of risks. How best to describe and structure the components of the various views and profile them in terms of attributes and values presents interesting research opportunities.

Developing the risk view

Risk events arise from the values of the attributes of the components in one or more views (organizational entities, physical aspects of the facility, schedule activities, etc.) which are risk drivers, the presence of which, either singly or in combination with other risk drivers, leads to the potential for a risk event occurring. Once the user has modelled the project context in the four project views, he is in a better position to develop a comprehensive risk register organized in the form of a hierarchy (category, sub-category, class, issue, event), which facilitates easy navigation, and then define the relevant properties of each component (e.g. at the event level, drivers, likelihoods, outcomes, mitigation measures). The term ‘risk issue’ corresponds to topics or keywords of like kind, of direct relevance to the project and around which there is a degree of uncertainty and thus associated risk events. For the current implementation, potential risk drivers are first associated with the risk issue at hand. Figure 2(a) shows an example of this for process issues under the foundation work sub-phase of the construction phase (see the left-hand side of Figure 2(b) where risk issues and corresponding events have been organized under project phase and project dimension, one possible structure of the risk register – the user is free to structure the risk register in accordance with their own preferences). From this set of issue drivers, the user can identify specific risk events as a function of risk driver attributes/values. For the example shown in Figure 2, by examining the process (schedule) view (right-hand side of Figure 2(b)), it is observed that the preliminary schedule indicates bridge foundation work is to be done in the timeframe 6 May to 30 July. For the river component of the environmental view, the value for the attribute of high water time window is mid-April to mid-June (not shown), so the timing suggests the potential for an adverse risk event, *high water/flood overtops bridge foundation work*. Not shown in the figure are performance measures likely to be affected (time, cost, safety). Thus, the ability to integrate information from various views of a project within a single system or to have ready access to similar information from multiple systems facilitates the task of risk identification, along with allowing the ready documentation of related risk drivers.

Knowledge management

Critical questions for many organizations are: (1) How does one retain their employee's project knowledge and experience to provide both added value to their customers in future projects or an edge above their competitors?; and (2) Given ever present time constraints and the level of effort required to develop a comprehensive representation of a project, what assistance is available to assist with this task? We have addressed these questions in part by designing and implementing a knowledge management feature, called the Standards Side of the system. For example, shown in Figure 1(e) is the ability to define an organizational/contractual master template or list. Although individual members of a class may not be known for a specific project, the ability exists to define classes of participants that are common to all projects, and for each class, define attributes that can be inherited down to the individual member level, either on the Standards Side if the type of member is known (but not specific identity), or on the project side when the template is copied over in whole or in part. Thus the user can draw upon an organization's experience accumulated over previous projects and documented in standardized master lists, speeding the representation process for a new project, while reducing the potential for omissions. Standards for other project views, including the risk view, are similarly supported.

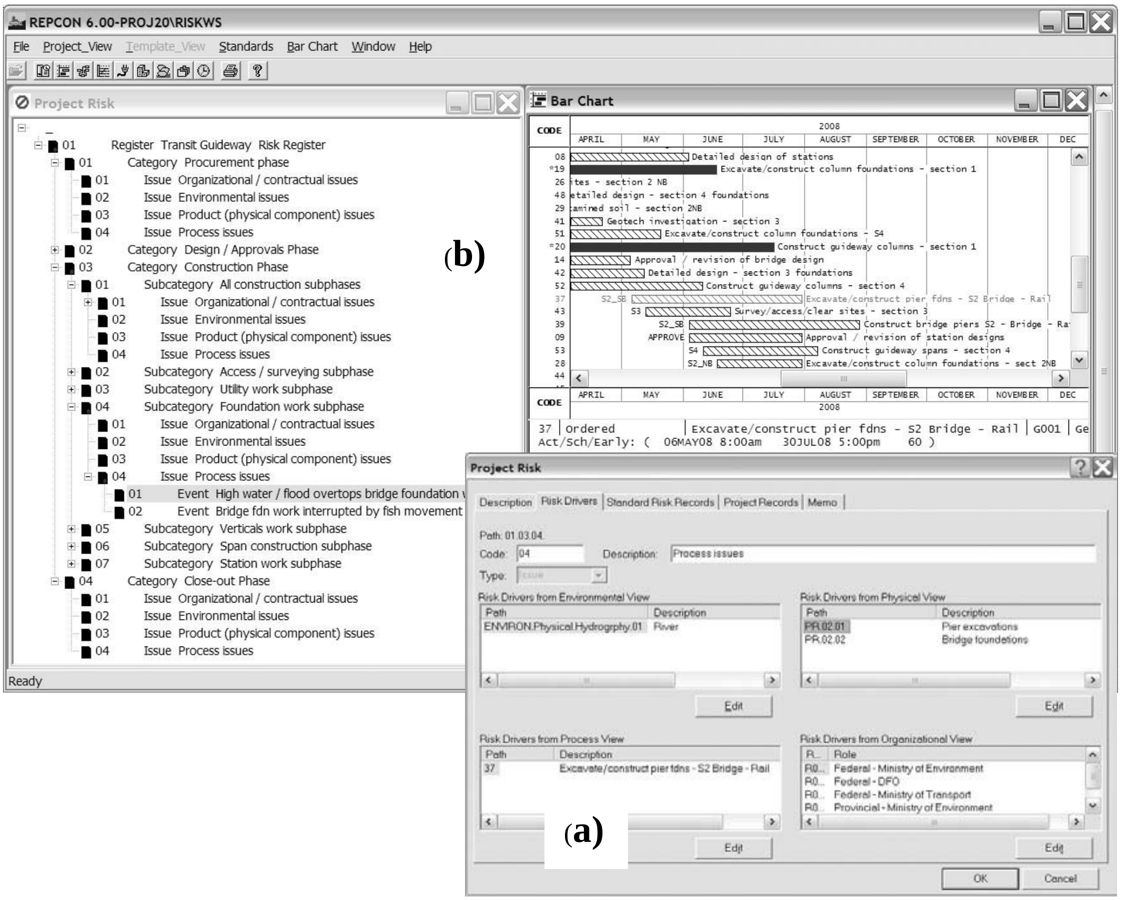


Figure 2: Identifying potential risk events based on risk drivers and their attributes

CONCLUSIONS

Described in this paper are aspects of a systematic approach using information technology to improve the risk management process. The approach offers several benefits, including development of a shared image of the project context among those charged with developing the project's risk profile, a direct linkage between project context and risk profile and the ability to document this linkage in the form of risk drivers, access to and easy use of past experience, and the ability to track the history of the project's risk profile. These benefits improve upon current risk management best practices applied on Canadian infrastructure projects; however, the limitation of the approach and accompanying tool lies with whether the project manager is willing to spend the necessary time and resources to develop a working model of the project context and integrate the approach with other project management processes. Ongoing work is directed at more comprehensive profiling of components used to represent the various views of a project in terms of attributes useful for risk management and other management functions, enhanced knowledge management capabilities, hybrid approaches to expert opinion elicitation (combined quantitative and qualitative approaches), interface issues in terms of allowing simultaneous access to data from all project views, and the use of visualization to gain insights into the risk profile of a project. Opportunities to apply the concepts to actual projects will continue to be pursued in order to refine the approach.

REFERENCES

Akintoye, A, Hardcastle, C, Beck, M, Chinyio, E and Asenoya, D (2003) Achieving best value in private finance initiative project procurement. *Construction Management and Economics*, **21**(5), 461–70.

Ayyub, B M (2001) *Elicitation of experts opinions for uncertainty and risks.* CRC Press.

Cooke, R M (1991) *Experts in uncertainty*: *opinion and subjective probability in science*. New York: Oxford University Press.

De Zoysa, G N S (2006) *Application and re-use of information and knowledge in managing risks of infrastructure projects*, PhD Thesis, Department of Civil Engineering, University of British Columbia, Vancouver, Canada, January 2006.

Hall, J W, Cruickshank, C and Godfrey, P S (2001) Software-supported risk management for the construction industry. *Civil Engineering*, **144**, 42–8.

Hillson, D (2003) Using a risk breakdown structure in project management. *Journal of Facilities Management*, **2**(1), 85–97.

Government of British Columbia Risk Management Branch and Government Security Office. (RMB) (2007) *Enterprise risk management (ERM) guidelines*, available at http://www.fin.gov.bc.ca/pt/rmb/ref/RMB_ERM_guideline.pdf (accessed 10 December 2006).

ICE (Integrated Computer Engineering Inc.) (2006) Risk Radar®: essential software for managing project risk, available at http://www.iceincusa.com/Products.aspx?p=Products_RiskRadar (accessed 10 December 2006).

Ling, Y (2003) A conceptual model for selection of architects by project managers in Singapore. *International Journal of Project Management*, **21**, 134–44.

Morgan, M G and Henrion, M (1990) *Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis*. New York: Cambridge University Press.

Nelms, C, De Zoysa, S and Russell, A (2006) Features of a risk management tool applied to a major building project. *In*: CD Rom *Proceedings of 1st International Construction Specialty Conference*, 23–26 May 2006, CSCE, Calgary, Alberta, Canada.

Newcombe, R (2003) From client to project stakeholders: a stakeholder mapping approach. *Construction Management and Economics*, **21**, 841–8.

NOWECO (Northwest Controlling Corporation Ltd) (2006) RiskEasy® Risk register risk management software, available at http://www.noweco.com/riskrege.htm (accessed 10 December 2006).

Olander, S and Landin, A (2005) Evaluation of stakeholder influence in the implementation of construction projects. *International Journal of Project Management*, **23**, 321–8.

PertMaster (PertMaster Project Analytics) (2006) PertMaster Project Risk, available at http://www.pertmaster.com/products/projectRisk.htm (accessed 10 December 2006).

Project Management Institute (PMI) (2004) *A guide to the project management body of knowledge* (PMBOK). Newtown Square, PA: Project Management Institute.

Russell, A D and Udaipurwala, A (2004) Using multiple views to model construction. Paper presented at the CIB World Building Congress, 2–7 May 2004, Toronto, Canada.

Wang, Y (2005) *Environmental risk modeling of infrastructure projects*, MASc Thesis, Department of Civil Engineering, University of British Columbia, Vancouver, Canada, May 2005.

PRACTICAL IMPLICATIONS OF LOCATION-BASED SCHEDULING

Niclas Andersson[1] and Knud Christensen

Department of Civil Engineering, Technical University of Denmark, DK-2800, Kgs. Lyngby, Denmark

The traditional method for planning, scheduling and controlling activities and resources in construction projects is the CPM-scheduling, which has been the predominant scheduling method since its introduction in the late 1950s. Over the years, CPM has proven to be a very powerful technique for planning, scheduling and controlling projects. However, criticism has been raised on the CPM method, specifically in the case of construction projects, for deficient management of construction work and discontinuous flow of resources. Alternative scheduling techniques, often called repetitive or linear scheduling methods, have proven to be well suited for projects of a repetitive nature, such as building projects. As the repetitive or linear scheduling methods may include locations or places, they are also referred to by the comprehensive term of location-based scheduling (LBS), which is the concept that will be used in this study. LBS is a scheduling method that rests upon the theories of line-of-balance and which uses the graphic representation of a flow-line chart. As such, LBS is adapted for planning and management of workflows and, thus, may provide a solution to the identified shortcomings of CPM. Even though LBS has a long history and is well grounded theoretically, it has gained generally little attention in the construction industry. Besides the theoretical research available on LBS, some studies report on the application of LBS, but empirical data on the practical implications of LBS is limited. This study rests upon three case studies of residential projects carried out in Denmark in 2006. The purpose is to test and evaluate the practical implications of LBS when applied on site. The study concludes, with emphasis from the site management involved, that improved schedule overview, establishment of workflows and improved project control constitute the three most important implications of LBS.

Keywords: critical path method, line of balance, location-based scheduling, scheduling, workflow.

INTRODUCTION

The coordination of activities and resources in order to establish an effective work flow is central to the management of construction projects. The Critical Path Method (CPM) constitutes the predominant technique for planning and scheduling of construction projects, since it was introduced in the late 1950s. Together with Gantt charts, the universal graphical representation of schedules, which was introduced by Gantt and Taylor in the early 1900, CPM provides the common corner stone in the vast number of scheduling software tools that have been developed (Kenley 2004).

CPM has proven to be a very powerful technique for planning, scheduling and controlling projects, especially for complex and non-repetitive work (Arditi *et al*. 2002). However, despite the dominance of the CPM-method, there is criticism raised on the method for the management of construction work. The criticism of CPM refers

[1] na@byg.dtu.dk

to the inability to manage and monitor resource limitations in a way that corresponds to the reality of construction, i.e. work that to a large extent is characterized by repetition (Kenley 2006). Repetitive activities are often characterized by imbalanced production rates (Arditi *et al.* 2002), which might lead to unforeseen work stoppages and, consequently, inefficient resource usage. The activities, and their logical connections, are the principal focus of the CPM-method, whereas resources are given minor attention as the CPM-method assumes there are unlimited resources available for executing the work. Consequently, CPM-based schedules, graphically represented by Gantt charts, may result in discontinuous resource usage that in turn will lead to interruptions in the production where each trade suffers from recurrent starts and stops during the project process. It is difficult to monitor the planned resource usage from a Gantt chart, as the different amounts of work and different pace of each trade is concealed in the bars of the activities.

As construction work is generally characterized by continuous or repetitive work, where the same activities are executed at various locations of a building or construction, construction scheduling appears to be more closely aligned to repetitive scheduling methods (Russell 2004) such as “Line-of-balance”, “Time-location Matrix Model”, “Construction Planning Technique”, “Time Space Scheduling method” (Harris and Ioannou 1998), “Flow-Line” (Kenley 2004, referring to Mohr 1991) and similar methods. Arditi *et al*. (2002) refer to those alternative scheduling techniques, developed over the last 30 years, by the generic term of “linear scheduling methods” and claim that those methods have proven to be well suited for projects of a repetitive nature. Harris and Ioannou (1998) suggest the generic term of “repetitive scheduling method” as those methods involve repetitive activities. Kenley (2004) points out that the linear or repetitive scheduling methods strongly suggest locations or places and, consequently, he introduces the comprehensive term of “location-based scheduling” (LBS).

However, despite the long history and a promising potential of these repetitive, linear or location-based scheduling methods, they have gained little attention among the practitioners of the construction industry. Finland, however, constitutes an exception. As a result of two decades of research and development, a comprehensive line-of-balance-based planning, scheduling and control system, has been developed and implemented among the main contractors in Finland (Seppänen and Aalto 2005). The conception of a system does, in this case, refer to a set of planning and scheduling functions such as a risk simulation module based on the Monte Carlo technique, a bill of quantities collecting the building materials of the project that are distributed among the activities, a procurement module for the supply of building material, a national database with building productivity data etc. The various functions of this planning, scheduling and control system are integrated in a commercial software package, originally named DynaProject™ and later versions called Control™, which empowers the Finnish line-of-balance based system. It has now become the prevailing planning methodology among the large contractors in Finland (Kankainen and Seppänen 2003). The Finnish scheduling system is based on a modified line-of-balance method, in which the y-axis of the flow-line chart is represented by the locations of the project, i.e. the y-axis consists of a hierarchical structure of the physical locations of the building or construction. This line-of-balance method, in this study, will be referred to by the term of location-based scheduling, a conception originally coined by Kenley (2004).

Figure 1 presents an example of a location-based schedule developed in Control™ in which the hierarchic location structure is presented along the y-axis and four activities repeat in the different locations of the building.

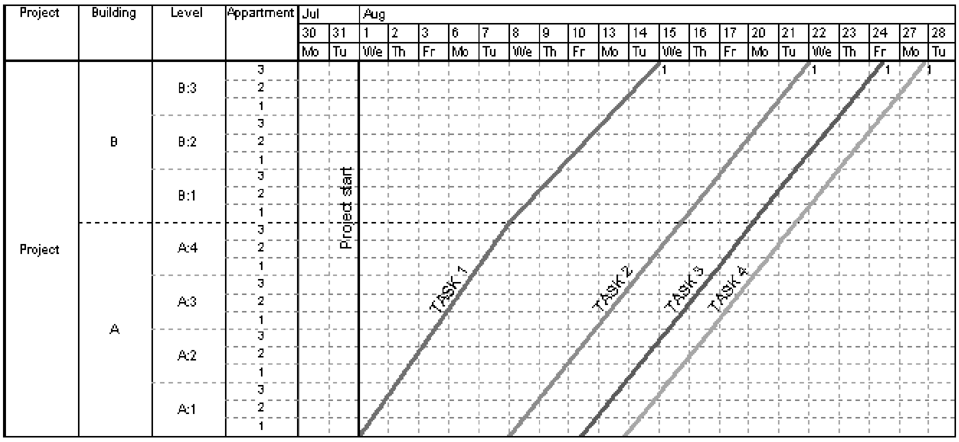


Figure 1: The graphical presentation of a location-based schedule in a flow-line chart

The flow-line chart of an LBS schedule, as seen in Figure 1, is adapted to planning and management of continuous work-flows, i.e. where resource groups can perform their work without interruptions caused by other resource groups working with other activities at the same location at the same time. Thus, LBS supports the establishment of continuous activities and a resource usage with limited waiting time and avoidance of work disturbance, and as such, LBS promotes the efficient use of resources and the delimitation of waste which corresponds to some of the principal elements of Lean construction. Kankainen and Seppänen (2003) describe the connections between LBS and lean construction, referring to the common focus on efficient resource usage and waste avoidance. Kenley (2004) explains that the application of lean construction requires a new approach to production planning and suggests LBS as a key to improve the selection of lean construction techniques. This argument rests upon the difficulties of identifying continuous workflows in a traditional CPM-based schedule, which consists of discrete activities.

Problem statement and delimitations

The argument for this study rests upon the identified shortcomings of the traditional planning and scheduling technique of CPM in the context of construction, the current attention given to the implementation of lean construction and thereby an increased focus on flow-management and, finally, the fact that there is a LBS planning and scheduling software package recently developed.

The purpose is to identify and review the main practical implications of LBS when applied on a building project in conjunction with the management on site. The research area of the study relates to the subject fields of construction management and logistics, where planning, scheduling and control are in focus. It is not within the scope of the study to develop either the scheduling method of LBS or the software tool.

Research method

The study focuses on the production phase of construction, i.e. the planning and scheduling of the activities that take place on site. Three building cases that represent typical Danish residential building projects constituted the empirical input to the study. Case 1 is a new residential building project with an 11-storied house, 144 apartments, and a total living space of 13,500m^2. Case 2 is a renovation project that includes the modernization of bathrooms, façades, windows, roofing etc. It includes 10 separate building blocks, including 385 apartments, and has a total budget of fully 40 million EUR. Case 3 is another new residential building project with 225 apartments, a living space of 20,000m^2 and a total budget of about 30 million EUR. The three largest Danish contractors were assigned as general contractors in each of the three cases. The building cases, according to the plan, will be delivered between mid 2007 and 2008.

The research in all three cases was designed as practical tests of LBS in close collaboration and dialogue with the management on the sites. The schedules that were established by the site management in each case provided the starting point for the test of LBS. Thus, the initial step was to transform the original CPM-based schedules that were developed for each case into LBS versions. For Case 1, this step is exemplified in Figure 2. In the next step, the established LBS-copies of the original schedules were worked up and were adapted to an LBS configuration. Figure 3 shows the optimized schedule for Case 1. The findings from the analysis of the three cases corresponded basically, which is why the schedules from only one of the cases are presented. All the empirical results have continuously been discussed and evaluated in dialogue with the construction managers and other relevant staff members of each case.

All schedules were developed using the scheduling software of Control™ 2005 or the later version Control™ 2007, developed by Graphisoft. An early version of the software, named DynaProject™, is referred to in the text. Graphisoft has facilitated the study with professional support regarding the application of the software.

The empirical data collection was carried out in 2006, from September to December.

ABOUT LOCATION-BASED SCHEDULING

The literature on LBS, or other repetitive scheduling methods, includes a theoretical direction, which is the greater part, and a field that reports on the application of LBS in practice. The theoretical direction typically deals with simulations or algorithms and heuristics, e.g. for optimization of resource continuity to achieve duration cuts and to model learning curves (e.g. Kang *et al.* 2001). An underlying presumption in this type of work is that LBS mainly is a tool for highly repetitive work (e.g. multi-storey buildings or road constructions) and, consequently, is not suitable for non-repetitive work. The theoretical work provides a solid foundation to the LBS-method, but it does not reveal whether LBS meets the demands of planning, scheduling and control on site and in different kinds of projects (Soini *et al.* 2004).

As indicated earlier in the text, there is a discussion going on about the argumentation that LBS has the potential to support a greater acceptance of lean construction. Kenley (2004), for example, claims that LBS allows the management of projects according to Lean concepts, including work flow, production reliability, supply chain management and just-in-time delivery. Mendez and Heineck (1998) describe a production preplanning process in which interdependent tasks are lumped together into main activities for which the number of crews that must be allocated to each task is calculated in order to achieve a balanced production pace. Kankainen and Seppänen (2003) add to the discussion about how interdependent tasks are merged together in summary activities on a master schedule level, where the activities are balanced in relation to production rate, locations and continuity, and where the summary activities are divided into delimited tasks at a detailed schedule level in order to achieve the desired level of schedule accuracy. Kankainen and Seppänen (2003) support the argument that LBS promotes the philosophy of Lean.

Kenley (2004) as well as Kankainen and Seppänen (2003) and other Finnish authors have contributed to the understanding of adopting LBS in practice and report on the experiences of using the DynaProject™ software as a practical tool to help control the project on site. However, one should be conscious about that some of the Finnish authors that report on the benefits of LBS and the advantages of using DynaProject™ (or later versions) are connected to the development of the commercial software tool.

PRACTICAL IMPLICATIONS OF LBS

The practical examination of LBS took its starting point in the existing schedules that were prepared by the site management for each of the three cases of the study. All the original schedules were prepared without any consideration of the study and it is therefore likely to believe that the schedules represent typical examples of production schedules in Danish construction projects of today. The site management in all cases used the traditional activity-based scheduling method of CPM, where the schedules typically were developed in MS Project and represented in a Gantt chart. The original schedules covered the production phase of each project, i.e. they represented the so-called production or master schedules of the respective projects. A review of the original schedules in the three cases maintained that they were generally characterized by:

- An extensive number of activities.
- Activities were organized in a WBS-structure.
- Interdependencies between activities were normally, but not always, appointed.
- Resources were delimited to labour, i.e. building materials or equipment/machinery were not considered.
- Resources were allocated solely to “own” activities, i.e. subcontracted work were not resource allocated.

As the original schedules were translated into LBS-copies, as shown in Figure 2, some common remarks were identified and reviewed together with the site managers. For example, the number of activities in the original CPM-schedules were substantially reduced in the LBS-version and consequently, made it possible to overview the whole schedule. It was also observed in the original schedules that the planned work flow of activities through the different locations of the building was frequently discontinuous, i.e. the production was typically characterized by frequent starts and stops for the various working crews.

Further, parallel activities were not always properly balanced in respect of their production pace. In some cases, this led to overlapping activities, which meant that two or more activities were planned to take place at the same location at the same time. The LBS-versions of the original schedules also revealed that there were a number of unused areas in each case, which also can be a consequence of unbalanced activities. An unused area signifies one or more locations where no work takes place during a period of time and, consequently, it indicates that the project can be scheduled in a more appropriate way.

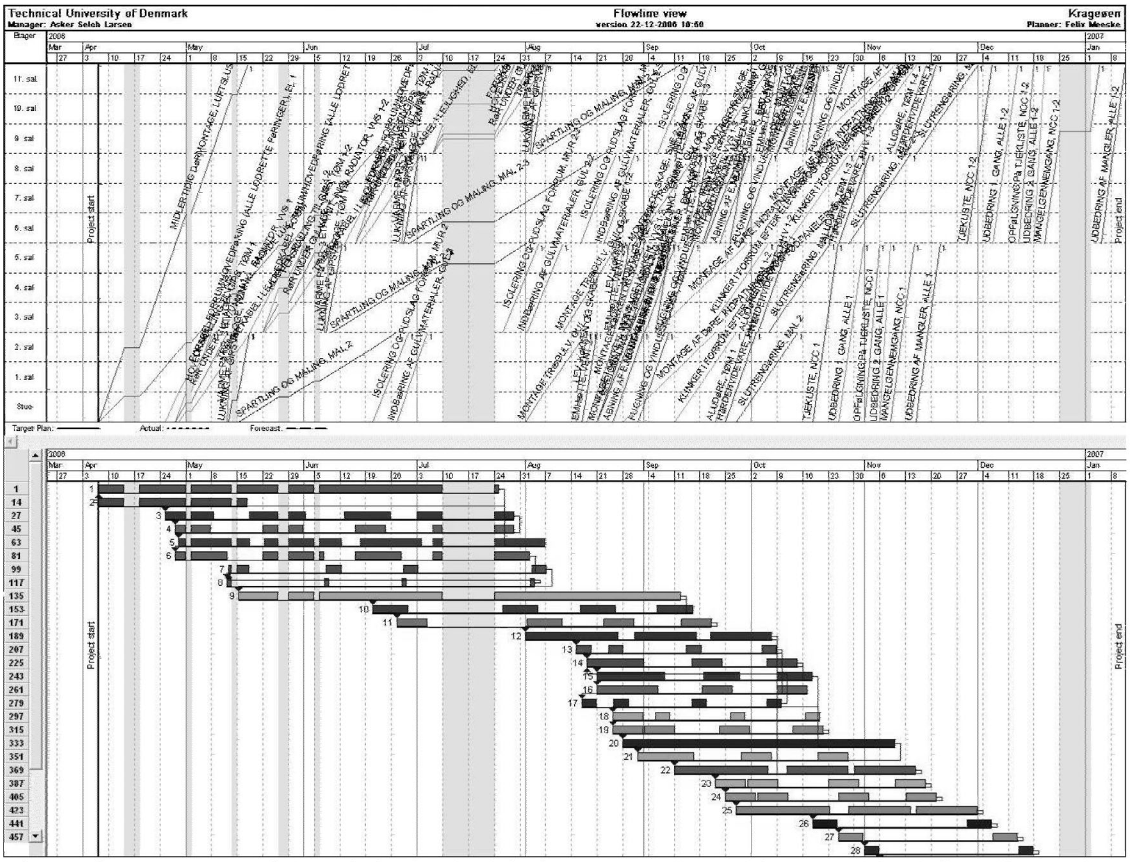


Figure 2: LBS-copy of the original schedule for Case 1 showed in a combined flow-line and Gantt-chart view. (Source: Larsen and Meeske 2007)

Based on the review of the original LBS-versions of the schedules, improvements were made in order to optimize the production planning. Figure 3 shows the optimized version of the LBS-schedule for Case 1 shown in Figure 2, which makes it possible to compare the two versions of the schedule. The analysis of the other two cases showed similar results as in Case 1, which is why the schedules from only one of the cases are displayed.

The processing of the LBS schedules revealed three major constructive implications of LBS, emphasized by the site management, namely improved schedule overview, establishment of work-flows and enhanced project control.

Improved schedule overview

The most immediate comment on the flow-line view, valued by the site managers, was the improved possibility to get an overview of the project and to actually see the activities repeating in various quantities through the multiple locations of the project. This simple implication of LBS and the flow-line view was considered a key aspect of LBS, and it constitutes a prerequisite for the establishment of work-flow and the enhanced project control.

Communication with subcontractors and other parties involved in the project is an aspect that gained from the LBS schedules as they were easier to understand and, consequently, easier to implement. This aspect of LBS is also expressed by Kenley (2004) who states that traditional project scheduling is frequently failing when it comes to communicating the management of a project from the management level down to the general site personnel.

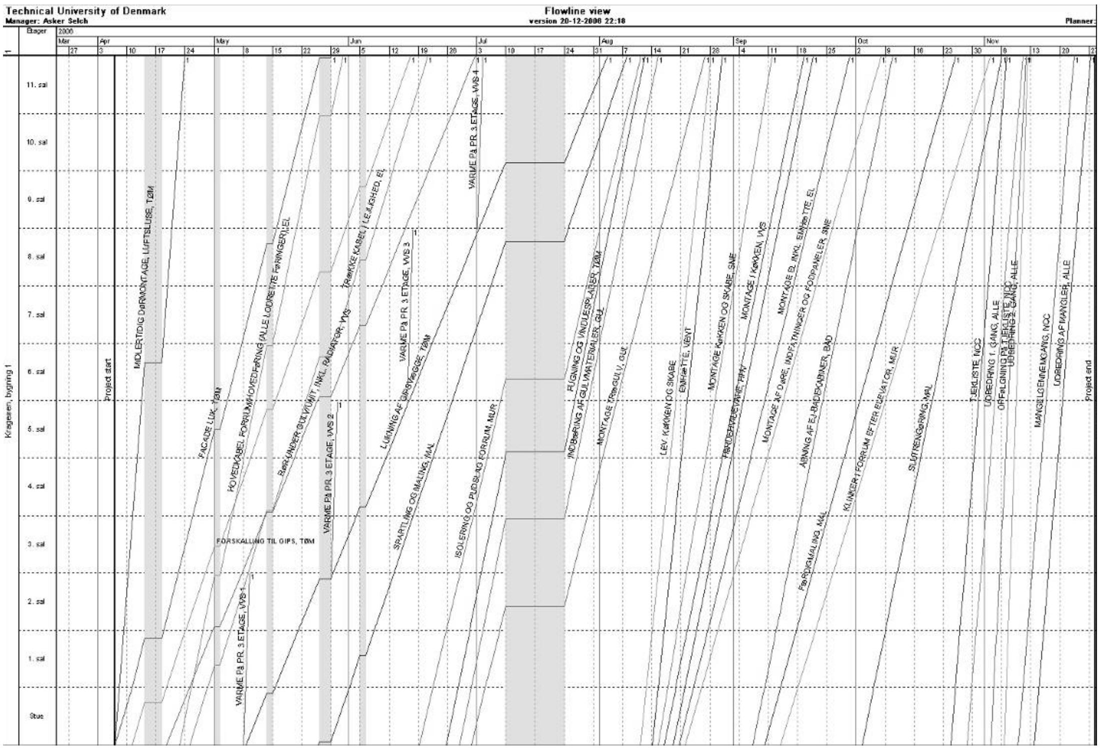


Figure 3: Improved LBS schedule for one of the three cases shown in a flow-line view (Source: Larsen and Meeske 2007)

Establishment of workflow

As indicated in the review of the original schedules developed for the three cases, it is difficult to ensure continuous workflows from a Gantt chart. The LBS schedules, however, provide information about the location of work and allocated work crews, which enables planning of continuous workflows (flow of resources through locations), avoidance of overlapping work (two or more crews working at the same location at the same time) and, possibly, avoidance of unused locations. Further, the graphical visualization of the production pace of the activities makes it possible to balance parallel activities, i.e. to adjust the resource units allocated in order to establish a sufficient production rhythm in a group of parallel activities.

LBS allows for simulations of different completion orders of the workflows following the defined locations of the project. This implication of LBS follows from an additional type of dependencies, i.e. location-dependencies, that comes with LBS. By changing the place completion order of an activity, for example from floor 1-2-3-4 to 4-3-2-1, the most sufficient completion order can be evaluated. This was of particular interest in one of the three cases where the installations originally were planned to commence at the top level of the building and continue down to the ground floor, but where a simulation in the processed LBS schedule showed that it was beneficial to commence the installations at the ground floor.

Figure 3 shows the processed LBS-version of the original schedule shown in Figure 2. It is manifested that the revised schedule includes continuous workflows that are balanced without overlaps at any time and that the empty locations are reduced.

Enhanced project control

The simple fact that an LBS schedule provides information about the planned location for each resource crew at a given time supports and simplifies project control of the work performed at each location, besides, it is generally valuable for the site management to know the precise location of a specific resource crew. In that respect, it is worth mentioning that a fundamental principle in LBS is that an activity should be fully completed in one location before the crew moves on to the next location. This principle involves a change in the current situation of planning and management of subcontracted work where the subcontractors more or less are indulged to consider their scheduled activities as a time-limit during which they are allowed to carry out the work as they whish, without respect to a specific location succession (see, for example, Conlin and Retik 1997 for more details on this subject). The insufficient consideration of the subcontractors' resources in the original schedules of the three cases, reveal that the planning and scheduling of subcontracted work can be improved. Kankainen and Seppänen (2003) suggest that agreements on payments should be connected to the work completion of locations in order to compel the subcontractor to conclude their work in the planned succession.

Seppänen and Aalto (2005) point out that improved schedule control, besides the possibility to examine how deviations from weekly plans influence the master schedule, is a significant benefit of LBS. An interesting point in this connection, presented by Kankainen and Seppänen (2003), is that the master schedule never should be updated even when the weekly schedules indicate deviations from the plan. They explain that this is because updating the master schedule will not solve the deviation problems, but rather transfer the problems towards the end of the project where they will accumulate. This is, however, an implication of LBS that is not tested or confirmed in this study.

Experienced difficulties in the application of LBS

The site management of the tree cases had none or limited experience from LBS when the study was initiated and even though the results describe LBS in generally positive terms, the study also experienced difficulties in relation to LBS. Some difficulties were directly connected to the application of LBS or the LBS-software that was used, while other problems were of a more general nature.

LBS implies a new, or preferably unfamiliar, scheduling method which requires a new approach to scheduling and it involves new conceptions. For example, LBS requires the definitions of locations and there are different more or less appropriate ways of dividing the project into locations. One aspect is about finding a sufficient level of details required for the planning, scheduling and control of the project. It is possible, but very inconvenient, to change the level of detail once the scheduling has commenced. Another difficulty experienced in one of the cases concerned the definition of different kinds of locations, e.g. how to handle ground works in relation to the locations that are connected to the actual building. The study found no guidelines for the proper approach to defining locations.

Well-known concepts of the CPM-method become irrelevant besides the introduction of new terms. For example, the concepts of critical chain and float fail as LBS principally concern the management of workflows where resource constraints become a central aspect. In connection to this, the new concepts of synchronized and paced activities become relevant. Synchronized activities imply that crews are sized in order for activities to proceed at the same pace, and paced means that crews proceed continuously through locations. Instead of the traditional total and free float, LBS includes buffers that somehow replace the conception of free float. Another difference from the traditional scheduling method is location dependencies, which caused some initial problems in the cases. Activities in LBS are location dependent on a certain hierarchy level or location independent, and it is for the manager to decide on the appropriate hierarchy level for each activity.

Besides the LBS specific difficulties, some general problems that cannot be directly connected to the specific application of LBS were identified. For instance, it became an apprehension among the site managers that the LBS software requires a significant amount of input information in the initial stage of the planning process. This is a consequence of the design of the LBS software, which uses a bill-of-quantity as the starting point for definition of activities. Thus, the LBS software calculates activity durations from a selection of the bill-of-quantity allocated to a specific activity together with the resources that are allocated and information on productivity for the specific type of work. The site management in this study experienced, which ought to be typical in a Danish context, that they did not have access to a coherent bill-of-quantity for their respective projects. Thus, activity durations were generally valued on basis of the site managements' individual experiences rather than extracted from bill-of-quantities, documented productivity data or specified numbers of resource units.

This study argues, however, that this is not a problem associated with LBS as such, but rather a consequence of the lack of a coherent and standardized information structure in the Danish context. In Finland, a productivity database with information on construction activity data has been developed by a joint effort of the construction industry, which of course facilitates the information management. Finally, it is worth mentioning that it is not a definite requirement for neither LBS scheduling in general nor the specific LBS software to use a bill-of-quantity.

CONCLUSION

The evaluation of LBS for the on-site management of building projects revealed, emphasized by the site management involved in the study, three major beneficial practical implications of location-based scheduling. First, the improved overview of the project schedule from the flow-line view of LBS supports, not only the understanding of the schedule, but also the communication with subcontractors and other involved parties and thereby it facilitates the implementation of the schedule. Second, LBS schedules support planning of continuous workflows of resources through locations, avoidance of overlapping work on the same location at the same time and avoidance of unused locations. Third, LBS supports improved project control as LBS provides information about the planned location for each resource crew at a given time, which facilitates the monitoring of work performed at each location.

Thus, it is confirmed from the three cases that LBS provides some practical implications beneficial for the on site management of building projects. This conclusion principally concurs with the findings reported in previous studies, e.g. Kenley (2004), Seppänen and Aalto (2005) and others.

The identified difficulties with the application of LBS were either LBS-specific or of a more contextual nature. The application of LBS requires basic knowledge about the LBS method and it implies the introduction of new software tools that, all together, involve new conceptions and a new approach to scheduling, which initially will challenge the site management. Another experienced difficulty was related to the general lack of a coherent and standardized information system that would facilitate the application of the LBS software. However, it is concluded in this study that a bill-of-quantities is not a definite requirement in the application of LBS or the specific

LBS software that has been used. This is rather to be considered a possibility to further develop the applicability of LBS, as a bill-of-quantity would allow for, e.g., coordinated procurement planning, material delivery schedules and on-site logistics.

REFERENCES

Arditi, D, Tokdemir, O B and Suh, K (2002) Challenges in Line-of-Balance Scheduling. *Journal of Construction Engineering and Management*, **128**(6), 545–56.

Conlin, J and Retik, A (1997) The Applicability of Project Management Software and Advanced IT Techniques in Construction Delay Mitigation. *International Journal of Project Management*, **15**(2), 107–20.

Harris, R B and Ioannou, P G (1998) Scheduling Projects with Repeating Activities. *Journal of Construction Engineering and Management*, **124**(4), 269–78.

Kang, L S, Park, C and Lee, B H (2001) Optimal schedule planning for multiple, repetitive construction process. *Journal of Construction Engineering and Management*, **127**(5), 382–90.

Kankainen, J and Seppänen, O (2003) A Line-of-Balance Based Schedule Planning and Control System. *In*: *11th Annual conference on Lean Construction*, 22–24 July, Virginia Tech, Blacksburg, Virginia, USA. International Group of Lean Construction.

Kenley, R (2006) Location-based Management. *In: 31st AUBEA Conference*, 11–14 July, The School of the Built Environment, University of Technology Sydney, Australia. Australasian Universities Building Educators Association (AUBEA)

Kenley, R (2004) Project Micromanagement: Practical site planning and management of work flow. *In: 12th Annual Conference on Lean Construction*, 3–5 August, Elsinore, Denmark. International Group of Lean Construction.

Larsen, A S and Meeske, F (2007) *Location-based Scheduling*, MSc thesis, Department of Civil Engineering, Technical University of Denmark.

Mendez, R and Heineck, L (1998) Preplanning Method for Multi-Story Building Construction Using Line-of-Balance. *In: 6th Annual Conference of the International Group for Lean Construction*, 13–15 August, Guaruja, Sao Paulo, Brazil. International Group of Lean Construction.

Mohr, W E (1991) Project Management and Control. *In: 5th Edition*. University of Melbourne, Department of Architecture and Building, Australia.

Seppänen, O and Aalto, E (2005) A Case Study of Line-of –Balance Based Schedule Planning and Control System. *In: 13th Annual conference of Lean Construction*, Sydney, Australia. International Group of Lean Construction.

Soini, M, Leskelä, I and Seppänen, O (2004) Implementation of Line-of-Balance based Scheduling and Project Control System in a Large Construction Company. *In: 12th Annual conference of Lean Construction*, Elsinore, Denmark. International Group of Lean Construction.

TRACKING AND FORECASTING PERFORMANCE OF EARTHMOVING OPERATIONS USING GPS DATA

Adel Alshibani[1] **and Osama Moselhi**

Department of Building Engineering, Concordia University, 1190 Du Fort, Montreal, Quebec H3H 2B5, Canada

Tracking and forecasting performance of earthmoving operations during construction is a crucial task that requires close monitoring of the equipment involved. Traditionally, monitoring is based on human involvement in data collection. Such monitoring process is labour intensive, expensive, time consuming, and not necessarily accurate. This has been recognized as a challenging task for project managers. This paper presents a new method designed to overcome the previously stated limitations. The proposed method automates site data collection and forecasts time and cost of earthmoving operations at completion and/or at any intermediate time horizon based on data collected using GPS. It utilizes spatial technologies including Geographic Information System (GIS) and Global Positioning System (GPS). GIS is employed to automate data acquisition and to analyse spatial data. GPS is used to automate site data collection in near real time. The GPS data are used to estimate onsite crew productivity and to forecast time and cost. The proposed method utilizes project ratio techniques and earned value and presents a methodology that allows for more accurate forecasting of project time and cost. The developed methodology has been coded in prototype software using object-oriented programming. An example project is analysed to demonstrate the features of the developed method.

Keywords: adaptive, cost, earthworks, equipment, forecasting.

INTRODUCTION

In large-scale earthmoving operations, measuring actual performance and forecasting project time and cost during its execution are crucial management functions for the successful delivering of this class of project. Measuring actual performance enables comparison with the as-planned progress. This comparison enables the determination of project status and assists in identification of the cause(s) behind unacceptable performance so that corrective action(s) can be taken. Accurate measuring of actual performance relies on the accuracy of the data collected from construction sites, whereas accurate and efficient forecasting of project cost and time relies on the method applied and the timely collection of site data.

In this class of project, estimating actual performance requires collecting large amounts of data from construction sites. Traditionally, site data collection has been commonly based on manual methods, in which the collected data are recorded on paper by human observers. Manual methods are recognized to be costly and not necessarily accurate (John *et al*. 2005).

[1] yasienadel@hotmail.com

Problems associated with measuring actual performance have been widely recognized and are well documented (Bassioni *et al*. 2004). The industry has benefited, in recent years, from new automated field data collection tools that are able to gather large volumes of necessary data in a timely manner. Automation of site data collection leads to improvement of project tracking and control systems (Oglesby *et al*. 1989). In large-scale earthmoving operations, the most widely used automated systems for site data collection are: (1) On-board Instrumentation Systems (OBIS); and (2) Global Positioning Systems (GPS). The OBIS has been used in several earthmoving applications, including controlling scraper wheel slippage and transmission shifting, maximizing dozer production, providing increased traction to haul trucks, and preventing loader rollovers (Chironis 1987). On the other hand, the GPS in such application is relatively new. Some innovative applications, however, have been reported in recent years. This includes collusion avoidance of excavating equipment (Lothon and Akel 1996), monitoring asphalt compaction (Oloufa and Thomas 1997), and estimating duration of earthmoving operations (John *et al*. 2005). The main advantages of GPS over OBIS are: (1) it is inexpensive; and (2) it can collect data in near real time.

Literature suggests that data collected by GPS have not been used in estimating and forecasting performance of earthmoving operations. In addition to site data collection, considerable efforts have been made in developing effective methods to forecast project cost and time at completion and at target date. Each of these methods has its own assumptions (Hassanien 2002). Most of these methods are based on earned value (Moselhi *et al*. 2004; Moselhi and Hassanien 2003; and Alshibani 1999). Others employ stochastic modelling (Gabriel *et al*. 2004), or project ratios (Eldin and Hughes 1992). These methods were developed for building construction projects except for that of Moselhi and Hassanien (2003), which was designed for linear projects such those involving earthmoving operations. They all assume that either the established performance at the report date will continue until completion or the remaining work after the report date will be performed as planned, entirely blocking out certain time periods during which exceptional conditions are known to have prevailed; they estimate actual performance based on data collected manually.

This paper presents a newly developed method in an effort to circumvent the above stated limitations of current methods. The proposed method utilizes spatial technologies including GPS and GIS to automatically: (1) collect data from construction sites in near real time using GPS receivers; (2) estimate actual performance, and forecast projects' time and cost at any time horizon using GPS data. The paper focuses primarily on estimating actual productivity and on forecasting project time and cost at completion and at any projected time horizon. The developed method for forecasting is self-adapting and utilizes the earned value concept (Department of Defence 1967) and project ratios technique (Eldin and Hughes 1992).

PROPOSED METHOD

The proposed method incorporates three modules; (1) Database Module; (2) Graphical User Interfaces (GUI) Module; and (3) Geographic Information System (GIS) Module. Figure 1 represents the main component of the proposed method. The Database Module is designed to store: (1) the positioning data collected by GPS for tracking equipment on construction sites in near real time; (2) the swell and shrinkage factors for various soil types; and (3) available equipment pool. The function of the GUI Module is to acquire non-graphic data such as data pertinent to job and management conditions and actual cost data. The GIS Module performs the analysis of collected GPS data and depicts moving equipment on the map in layers.

The proposed method involves five major steps: (1) collecting site data using GPS receivers; (2) mapping moving equipment by transforming its GPS positioning data (longitude, latitude, speed, time and direction) into GIS to develop a graphical representation; (3) analysing GPS data to account for the number of cycles (trips) the tracked equipment makes within a particular period of time; (4) estimating the actual productivity rate; and (5) forecasting project time and cost. The following sections focus primarily on: (1) estimating actual productivity using GPS data as a novel method, and (2) forecasting project cost and time.

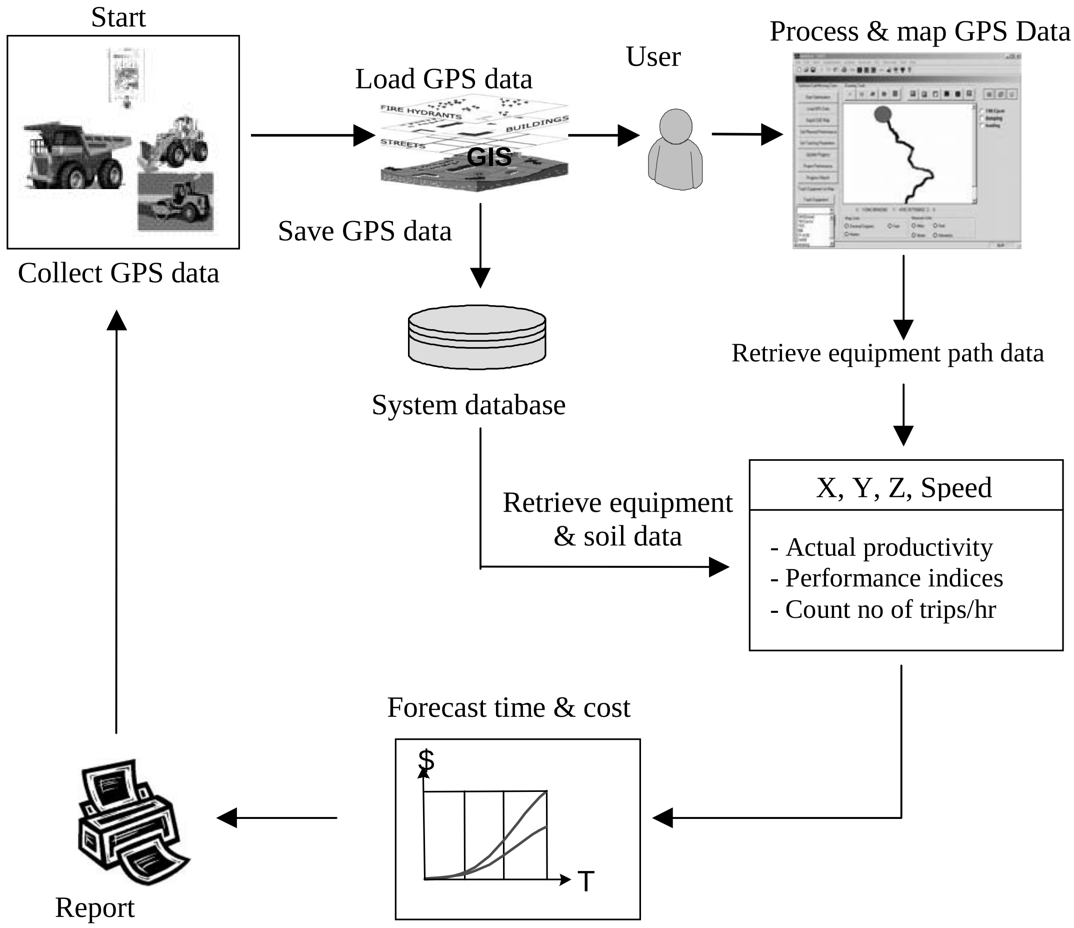


Figure 1: Main components of the proposed method

Estimating actual productivity

In order to measure project actual performance and forecast its status with respect to time and cost, the method first estimates the crew actual productivity based on the spatial data collected by the GPS receiver. The method tracks (counts) the number of cycles (trips) the equipment makes within a particular period of time. The cycle-time equals the summation of loading, travel, dumping and return time. The loading time is determined when the equipment is positioned in the loading area, the travel time is determined when the equipment moves from loading to dumping area(s), the dumping time is determined when the equipment is positioned in the dumping area, and the return time is determined as the time required for the equipment to move back from dumping to loading areas. Upon completion, the crew actual productivity is estimated considering the type of construction equipment involved. All the data needed for estimating actual productivity are stored in the system's database. In general, the actual productivity for hauling units such as trucks and scrapers can be estimated as follows:

$$(\text{P/hr})_i = (\text{No of hauling unit})_i \times \text{No of trips per hour} \times \text{Capacity} \times \text{Cf} \qquad (1)$$

in which:

$(\text{P/hr})_i$ is the estimated actual productivity per hour;

No of hauling unit is the number of hauling units in the crew;

No of trips per hour is the number of trips the hauling unit made in hour and it is accounted automatically using GPS data;

Capacity is the hauling unit capacity taking into consideration soil type, which is retrieved from the system's database;

Cf is a correction factor, entered by the user, and accounts for the efficiency factor, bucket fill factor, and job and management conditions.

It should be noted that Equation 1 can be easily adapted to suit other equipment such as compactors, graders and rollers. For example, the productivity of a compactor can be estimated in SF per hour as follows:

$$\begin{aligned}(\text{P/hr})_i = {} & (\text{No of compactors})_i \times \text{No of trips per hour} \times \text{Distance of segments} \\ & \times \text{Width of roll} \times \text{Cf}\end{aligned} \qquad (2)$$

Figure 2 represents the mapping of collected spatial data, used in estimating the crew

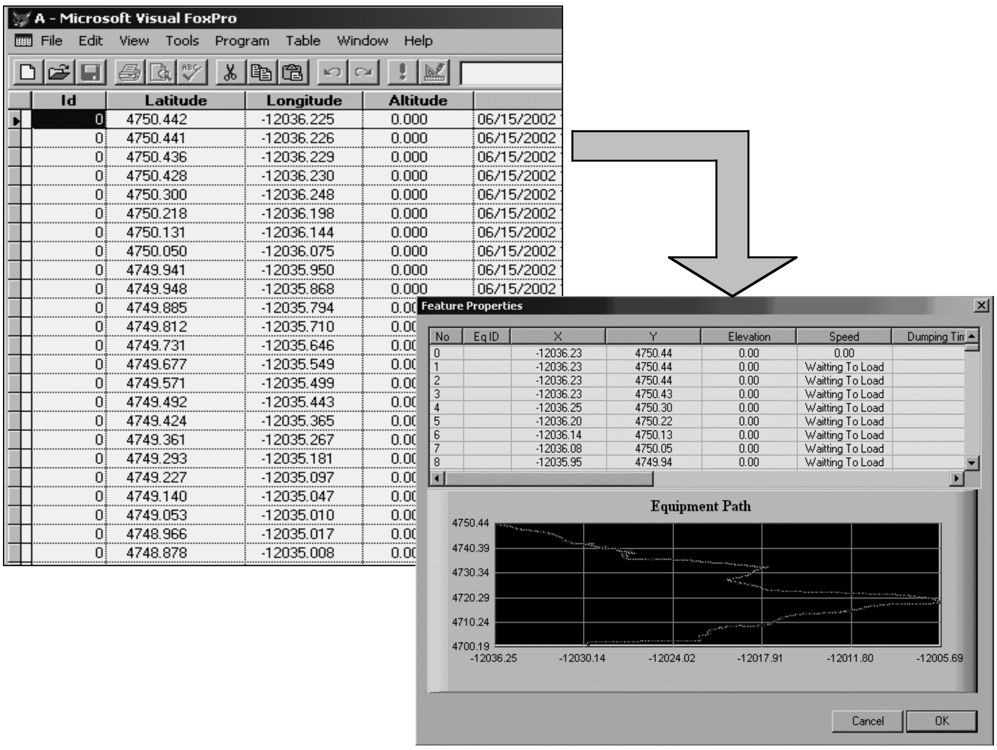


Figure 2: Mapping of spatial data

Cost and time forecasting

The proposed method utilizes the project ratios technique developed by Eldin in 1992 (Eldin and Hughes 1992) and the earned value concept developed by US Department of Defence (DoD) in 1967 (Department of Defence 1967) for forecasting project cost and time. In order to forecast time and cost, two project performance indices are calculated. These are: productivity performance index (PPI) or schedule performance index (SPI) and cost performance index (CPI). The two indices are calculated using the two methods referred to above.

Performance indices using project ratios technique

Productivity performance index

This index provides a measure of the likelihood of finishing the project within its targeted schedule and it is used here to forecast project duration. The index can be expressed as:

$$\mathrm{PPI} = \frac{(\mathrm{Whr/Q})\mathrm{b}}{(\mathrm{Whr/Q})\mathrm{a}} \tag{3}$$

in which:

PPI is the productivity performance index;

(Whr/Q)a is the actual to-date working hours per unit of work;

(Whr/Q)b is the budgeted working hours per unit of work.

Cost performance index

The cost performance index (CPI) provides a good measure as to how close a project will be completed within its targeted budget and it is used here to forecast project cost. The CPI can be expressed as:

$$\mathrm{CPI} = \frac{(\$/\mathrm{Q})\mathrm{b}}{(\$/\mathrm{Q})\mathrm{a}} \tag{4}$$

in which:

(\$/Q)b is the budgeted cost of unit rate;

(\$/Q)a is the actual cost to date of unit rate.

Forecasted cost and time at any point in time ($ti - t1$) can be calculated as follows:

$$\mathrm{C1}_{ti-t1} = \left(\mathrm{ACWP} + \left(\left(\frac{ti-t1}{\text{project time}}\right) \times (\mathrm{Q})\mathrm{b} - (\mathrm{Q})\mathrm{a}\right) \times (\$/\mathrm{Q})\mathrm{b}\right) \times \acute{a}_{\mathrm{c}} \tag{5}$$

$$\mathrm{C2}_{ti-t1} = \left(\mathrm{ACWP} + \left(\left(\frac{ti-t1}{\text{project time}}\right) \times (\mathrm{Q})\mathrm{b} - (\mathrm{Q})\mathrm{a}\right) \times (\$/\mathrm{Q})\mathrm{average}\right) \times \acute{a}_{\mathrm{c}} \tag{6}$$

$$\mathrm{T1}_{ti-t1} = \left((\mathrm{Whr})\mathrm{td} + \left(\left(\frac{ti-t1}{\text{project time}}\right) \times (\mathrm{Q})\mathrm{b} - (\mathrm{Q})\mathrm{a}\right) \times (\mathrm{Whr/Q})\mathrm{b}\right) \times \acute{a}_{\mathrm{t}} \tag{7}$$

$$T2_{ti-t1} = \left((\text{Whr})\text{td} + \left(\left(\frac{ti-t1}{\text{project time}} \right) \times (\text{Q})\text{b} - (\text{Q})\text{a} \right) \times (\text{Whr/Q})\text{average} \right) \times á_{t} \qquad (8)$$

in which:

$C1_{ti-t1}$ is the cost forecast1 @ ti – t1;

$C2_{ti-t1}$ is the cost forecast 2 @ ti – t1;

$á_{c}$ is the adaptive cost and it is calculated as follows:

$á_{c}$ = Forecasted Cost/Actual Cost

$á_{t}$ is the adaptive time and it is calculated as follows:

$á_{t}$ = Forecasted Time/Actual Time

$T1_{ti-t1}$ is the time forecast1 @ ti – t1;

$T2_{ti-t1}$ is the time forecast2 @ ti – t1;

$ti-t1$ is the time interval on horizon time;

(Q) b is the budgeted quantities;

(Q) a is the actual quantities up to report date;

($/Q)average is average actual cumulative to-date unit cost rate and it includes the normal unit cost rate achieved by the contractor in case there are exceptional conditions that are known to have prevailed in a certain period of time;

(Whr/Q) average is average actual to-date unit working hours and it includes the normal productivity rate achieved by the contractor in case there are exceptional conditions that are known to have prevailed in a certain period of time.

Performance indices using earned value concept

Schedule performance index

$$\text{SPI} = \frac{\text{BCWP}}{\text{BCWS}} \qquad (9)$$

in which:

SPI is the schedule performance index;

BCWP is the budgeted cost of work performed;

BCWS is the budgeted cost of work scheduled.

Cost performance index

$$\text{CPI} = \frac{\text{BCWP}}{\text{ACWP}} \qquad (10)$$

in which:

CPI is cost performance index;

ACWP is the actual cost of work performed.

The cost and time forecast at any point in time horizon ($ti - t1$) can be expressed as follows:

$$C1_{ti-t1} = \left(ACWP + \left(\left(\frac{ti - t1}{\text{project time}} \right) \times BCAC - BCWP \right) \right) \times á_c \tag{11}$$

$$C2_{ti-t1} = \left(ACWP + \left(\left(\frac{ti - t1}{\text{project time}} \right) \times BCAC - BCWP \right) \div (CPI)\text{average} \right) \times á_c \tag{12}$$

$$T1_{ti-t1} = \big((Whr)td + \big(ti - (\% \times (Whr)\,b\big)\big) \times á_t \tag{13}$$

$$T2_{ti-t1} = \big((Whr)td + \big(ti - (\% \times (Whr)\,b\big)/(SPI)\text{ average}\big) \times á_t \tag{14}$$

in which:

(CPI)-average is the average to-date cost performance index and it includes the normal CPI achieved by the contractor in case of exceptional conditions that are known to have prevailed at certain reporting periods;

(SPI)-average is the average to-date schedule performance index and it includes the normal SPI achieved by the contractor in case there are exceptional conditions that are known to have prevailed at certain reporting periods;

% is percentage complete to date;

(Whr)td is actual to-date working hours;

(Whr)b is budgeted working hours.

Determining two values of performance indices results in forecasting a range rather than a single crisp value. This could prove useful to project managers to examine the forecasted values and decide on which is more applicable to the case at hand and allow for reasoning about the forecasted project status. Equations 5 and 6 and Equations 11 and 12 will give different values, defining the forecasted range of project cost in this case. Similarly, Equations 7 and 8 and Equations 13 and 14 will give different values that define the forecasted project time.

Cost and time variances

In addition to forecasting project cost and time, the proposed method calculates project cost and time variances at any targeted future date. The cost variance (CV) is determined by subtracting forecasted cost from budgeted cost at that point in time. Similarly, the time variance (TV) is determined by subtracting forecasted time from that planned.

$$CV_{ti-t1} = \left(\frac{ti - t1}{\text{project time}} \right) \times (Q)b \times (\$/Q)b - \left(\frac{C1_{ti-t1} + C2_{ti-t1}}{2} \right) \tag{15}$$

$$\mathrm{TV}_{ti-t1} = \left(\frac{ti-t1}{\text{project time}}\right) \times (\mathrm{Whr})\mathrm{b} - \left(\frac{\mathrm{T1}_{ti-t1} + \mathrm{T2}_{ti-t1}}{2}\right) \tag{16}$$

in which:

CV_{ti-t1} is the cost variance at (ti – t1) in horizon time;

TV_{ti-t1} is the time variance at (ti – t1) in horizon time and measured in working hours.

The data needed to perform the analysis are retrieved directly from GPS data or entered directly by the user in the case of actual cost. Furthermore, the proposed method enables partially blocking out certain time periods during which exceptional conditions are known to have prevailed, such as a strike. Instead of blocking out the time period entirely, the performance index for this period is calculated based on the level of performance achieved by the contractor during normal conditions, just before the occurrence of such unusual conditions. For example if a strike occurred in the second period (2-1) as presented in Figure 3, instead of blocking out this period entirely, its performance index can be calculated at normal conditions just before the strike. In an effort to improve the accuracy of forecasting, the proposed method uses an adaptive, self-learning adjustment factor. The adaptive factor is generated at each reporting period and is the ratio of actual versus forecasted. This simple factor continuously adapts to the project environment and systematically reduces the gap between the forecasted and actual project status.

COMPUTER IMPLEMENTATION

As proof of concept, the proposed method has been implemented in an automated system using visual C++ V.6, object-oriented programming and Microsoft Foundation Classes (MFC) supported by GIS. The system's database is designed in a relational database using Microsoft Access Database Management System. A relational database management system is used because of its combination of power, simplicity, and ease of use (Kim 1989). The database stores the data needed for calculation. The developed software operates in Microsoft Windows's environment. The data flow and processing, in the proposed method, is represented in Figure 4.

The system accepts both graphic and non-graphic data. The system is activated through setting out of tracking parameters. It automatically progresses with the crew productivity analysis, measures the project schedule and cost status at the report date, and forecasts time and cost at completion. The analysis is essentially performed based on the user's selection of the tracking parameters and the level of detail required. The project status is represented by the cost performance index, the schedule performance index, the productivity performance index, and associated variances and forecasts. The software calculates the values of these variables using the earned-value concept, project ratios technique and developed extensions to these techniques.

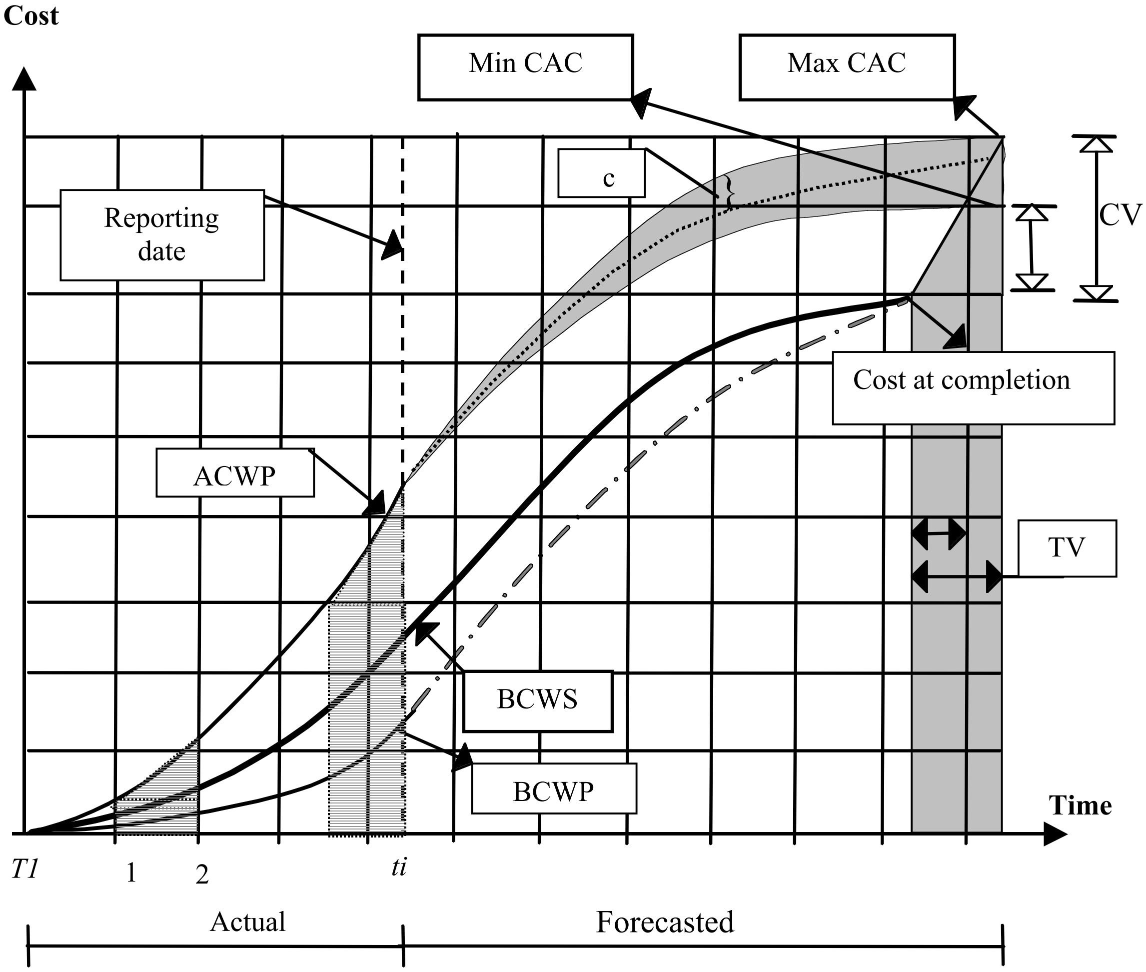


Figure 3: Cost and time forecast

Notes:

TV: time variances

CV: cost variances

ACWP: actual cost of work performed

BCWS: budgeted cost of work scheduled

BCWP: budgeted cost of work performed

CAC: cost at completion

Graphical User Interface

The Graphical User Interface (GUI) contains a series of dialog windows for the user to select from. The user interface incorporates menus, toolbars and dialog windows. The implementation of the GUI was carried out in a way that facilitates data entry and minimizes redundant data input. The GPS data are transformed to graphical presentation.

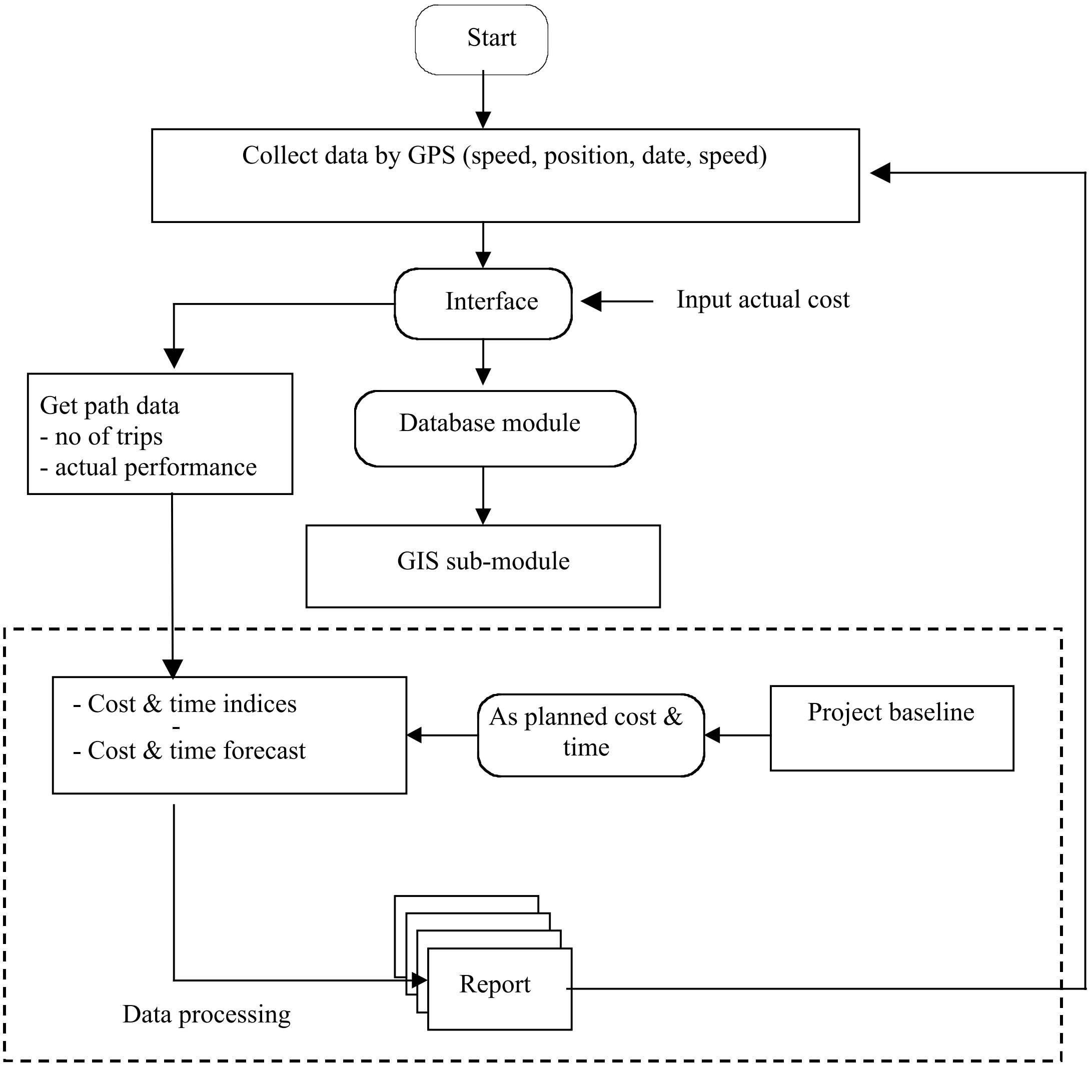


Figure 4: Data flow and processing in the proposed method

APPLICATION EXAMPLE

To illustrate the capability of the developed method in tracking and forecasting project performance, an example project is presented. The project involves moving of 100 000 cubic metres of dry clay from the pit to the site of a dam under construction. The crew formed to carry this job consist of one loader (994 CAT), 52 hauling units (740-Ejector) and one grader (24H (Global)).

Figure 5 represents a progress report taken after two days from the actual starting date (31 August 2006). The quantities of earth moved during this period are 5000 cubic metres. The actual cost incurred was $5000, $36 000 and $1500 for the loader, trucks and grader, respectively. The project is experiencing cost overrun but is ahead of schedule. The project would finish 95.8 hours earlier and at a $3994210.33 (–10280.52 – 3984067.02 + 137.21) cost overrun. It should be noted that the forecasting property page was designed to illustrate the projected range (i.e. minimum and maximum values) of cost and time, and their respective variances.

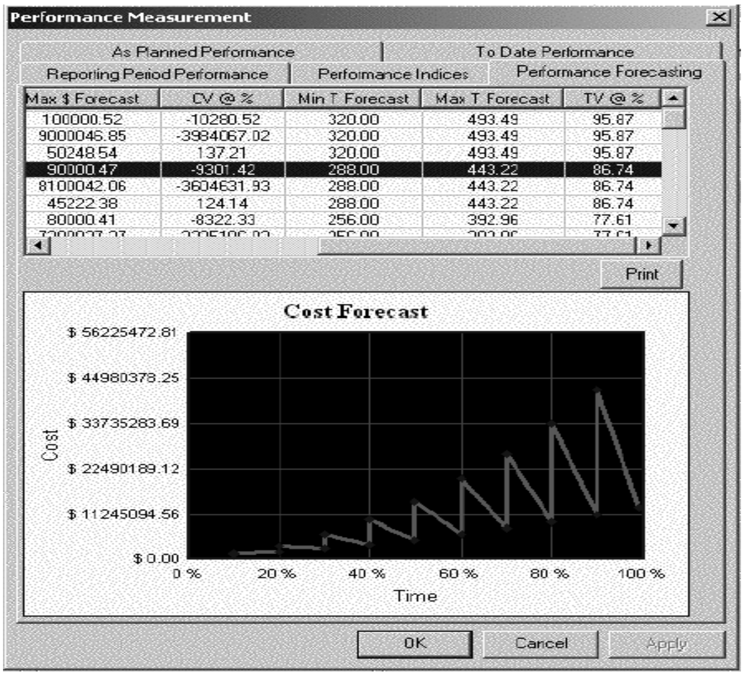


Figure 5: Forecasting dialog window

SUMMARY AND CONCLDING REMARKS

A new methodology for forecasting performance of earthmoving operations has been presented. The proposed method utilizes spatial technologies including GPS and GIS to circumvent some identified limitations in current methods. The methodology supports: (1) estimating actual productivity; (2) tracking the involved equipment in near real time to improve efficiency and productivity and to maximize contractor profit; and (3) forecasting project performance with a high level of confidence. Its basic components and the interconnectivity among them were described. The applications of GPS as a site data collection tool has been tested and proven to be accurate, effective and inexpensive. Integration of GPS and GIS makes it easy for project managers to track construction equipment on construction sites in near real time. The application of GPS and GIS for tracking earthmoving operations can solve problems associated with data quality and timing of information exchange among members of project teams. Timing of information exchange helps project management teams in taking corrective action(s) in a timely manner.

REFERENCES

Alshibani, A (1999) *A computerized cost and schedule control system for construction projects*, MSc Thesis, Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, Canada.

Bassioni, A, Price, A and Hassan, M (2004) Performance measurement in construction. *Journal of Management in Engineering*, **20**(2), 42–50.

Chironis, P (1987) Microprocessor-aided equipment proves productive and reliable. *Coal Age*, **92**(7), 48–56.

Department of Defence (DOD) (1967) Performance measurement for selected acquisitions. Department of Defence Instruction (DODI) 7000.2.

Eldin, N N and Hughes, R K (1992) An algorithm for tracking labour cost. *Cost Engineering*, **34**(4), 17–23.

Gabriel, A, Barraza, M, Edward, A and Fernando, M (2004) Probabilistic forecasting of project performance using stochastic S-curves. *Journal of Construction Engineering and Management*, **130**(1), 25–32.

Hassanien, A (2002) *Planning and scheduling highway construction using GIS and dynamic programming*, PhD Thesis, Department of Building, Civil and Environmental Engineering, Concordia University, Montreal, Quebec.

John, H, Michael, V and Julio, M (2005) Reduction of short-interval GPS data for construction operations analysis. *Journal of Construction Engineering and Management*, **131**(8), 920–7.

Kim, J (1989) *An object-oriented database management system approach to improve construction project planning and control*, PhD Thesis, University of Illinois, Urbana, Illinois.

Lothon, A and Akel, S (1996) Techniques for preventing accidental damage to pipelines. *In*: *Proceedings of the 1st International Pipeline Conference*, New York, ASME, Vol. 2, 643–50.

Moselhi, O and Hassanien, A (2003) Tracking and control of linear infrastructure projects. *In*: *5th Construction Specialty Conference of the Canadian Society for Civil Engineering*, 4–7 June 2003, Moncton, New Brunswick, Canada, NRC 45833, 141–9.

Moselhi, O, Li, J and Alkass, S (2004) Web-based integrated project control system. *Journal of Construction Management and Economics*, **22**(1), 35–46.

Oglesby, H, Parker, W and Howell, A (1989) *Productivity improvement in construction*. New York: McGraw-Hill.

Oloufa, A, Do, W and Thomas, R (1997) Automated monitoring of compaction using GPS. *In*: *Proceedings of the Construction Congress V*, 5–7 October 1997, Reston, VA, ASCE, 1004–11.

LINKING LEAN PRODUCTION AND SUSTAINABLE DESIGN ON WASTE REDUCTION

Aguinaldo dos Santos[1] and Carlo Vezzoli[2]

[1]*Rua General Carneiro, 460, EdifÃƒÂcio Dom Pedro I, sala 717, Curitiba ParanÃƒÂ¡, 80060-160, Brazil*
[2]*Politecnico di Milano Milano, Italy*

The present paper attempts to establish a connection between lean construction and sustainable design on the issue of waste reduction. Initially it presents the meaning of waste within the lean production theory and the correspondent heuristic approaches used in this area to reduce waste. It then presents the overall strategies adopted in sustainable design, focusing the review on the issue of ‘material life extension’. Finally, it presents a case study carried out in England that illustrates the implications of putting together lean principles and sustainable design. The overall conclusion is that dealing with waste using solely the lean construction theory is not enough and that better results are likely to be achieved by integrating sustainable design practices.

Keywords: design, lean construction, sustainability.

INTRODUCTION

Reduction of waste is one of the main focuses of lean construction. This is also a key issue in sustainable design where, like in the field of lean construction, there is already a considerable amount of knowledge developed both in terms of high abstract concepts and principles and in respect of heuristics and practical tools. Sustainability looks at all dimensions of the life cycle of a given product, including the production stage. However, only in the 1990s the link between production management and sustainable design began to be more clarified with a better understanding of environmental requirements for industrial products and through the concept of life cycle design (LCD).

Despite the clear link between both fields of research on the issue of waste there is little work attempting to connect their theoretical concepts and principles. In practice this lack of integration is also witnessed with companies applying sustainable design and lean production as separate managerial and technological battlegrounds. The next sections present insights on the implications of bringing these two different fields of research to work together.

PRINCIPLES FOR WASTE REDUCTION IN LEAN PRODUCTION

The lean paradigm sees the production system as a flow constituted of processing, waiting, inspecting and transporting activities. Within this model, processing activities

[1] asantos@ufpr.br

are the only ones that can add value to the customer and, therefore, waiting, inspecting and transporting are considered non-value-adding activities and should be eliminated from the main process flow.

Based on this model, a production system could be further described as a network of process flows and operations flows, lying along intersecting axes. A process flow is the designation for the flow of materials (or information) and represents the pathway in which raw material is transformed into semi-processed components and then into a finished product. An operations flow is the designation for the flow of humans or machines that carry on the work over each stage of the process flow. Operations are very diverse and dynamic in terms of content and position in time and space. The process flow should receive priority when searching for improvements in production systems. For example, and conventionally, most people simply think that improving transport efficiency refers to the adoption of forklifts or installing conveyors, etc. However, within the process/operation model, improving transport can also mean reducing or even eliminating the transport altogether. It is only after this broader analysis has been carried out in the entire 'process' that improvements should be devoted to the actual operation of 'transport' (Shingo 1989).

The aim of the flow model is to obtain 'lean production systems', with little or no waste of resources. Therefore, identifying and eliminating sources of waste is a constant preoccupation on the minds of people using this paradigm in their everyday activities. According to Imai (1997) and Shingo (1989), sources of waste (muda) are classified according to seven main categories:

1. Overproduction: this type of waste results from 'getting ahead' with respect to production schedules. Here the required number of products is disregarded in favour of efficient utilization of the production capacity.
2. Inventory: final products, semi-finished products, or parts kept in storage do not add any value. Even worse, they normally add cost to the production system by occupying space and financial resources and, also, by requiring additional equipment, facilities and manpower.
3. Repair/rejects: rejects interrupt production and, in general, require expensive rework. Moreover, they may end up discarded or damaging other equipment or generating extra paperwork when dealing with customer complaints.
4. Motion: any motion not related to adding value is unproductive.
5. Transport: although sometimes this activity seems to be an essential part of production, moving materials or products adds no value at all.
6. Processing: this waste happens when the use of inadequate technology or poor design results in inefficient processing activities. Sometimes this waste may appear as a consequence of a failure to synchronize processes, where workers achieve performance levels beyond or below the requirements of downstream processes.
7. Waiting: this waste occurs when the hands of a worker are idle such as when there are imbalances in schedule, lack of parts, machine downtime or when the worker is simply monitoring a machine performing a value-adding job.

This classification could extend further with the inclusion of vandalism, theft and other sources of waste. Koskela (1999) proposes the inclusion of a type of waste that occurs frequently in construction when production operates under 'sub-optimal conditions'. Congestion of a workstation in small places, work out-of-sequence and excessive stops in the flow are examples of these conditions that lead to production having sub-optimal performance (Ballard and Howell 1998; Koskela 1999). Formoso *et al.* (1999) add that on building sites it is possible to find waste due to 'substitution'. This waste happens when, for instance, there is a monetary loss caused by the substitution of a material by a more expensive one or when the execution of a simple task uses over-qualified workers.

There are many techniques available to analyse and improve production systems using the flow model as the conceptual base. They allow the analyst to understand actual behaviour, sequence, proportion and variability of inspecting, waiting, processing and transporting activities. Many of them were invented in the early days of Scientific Management School, such as time-lapse video recording, work sampling and flow charts. Obviously a given production process is often the direct result of the decisions taken at the design stage. The next section reviews the overall strategies of design that affected directly the reduction of waste not only at the production stage but during the entire life cycle of a given product.

PRINCIPLES FOR WASTE REDUCTION IN SUSTAINABLE DESIGN

Most authors in the field of sustainable design (Brezet and van Hemel 1997; Mont 2002; Charter and Tischner 2001; Manzini and Vezzoli 2002) agree that its leading principles include:

- the extension of the design horizon: from product design to the (systemic) design of the product life cycle stages;
- a new design reference: from product design to product function design.

Within this framework products have to be designed considering all phases of the life cycle. All activities related to the product, from the production of materials to its distribution, to its use and finally its disposal, are considered as a single unit. This leads to a shift from the design of the product to the design of the product-system, the whole of the processes characterizing its life cycle. Waste is then analysed looking at the entire flow of a material/product, far beyond the limits of production.

The second criterion is to design referring to the function delivered by the product, more than the physical product itself (Mont 2002; Vezzoli 2003). In fact it is in relation to this function (functional unit) that it is possible to assess whether the environmental impact has been reduced and how. Function, a fundamental and historic theme in the culture and practice of design, acquires in this context a new meaning and a new vitality. Waste could then be considered as any resource that does not add value to the functional unit.

When discussing LCD it is useful to bear in mind some of the criteria and guidelines that can direct product development towards smaller environmental impact:

- material consumption reduction;
- energy consumption reduction;
- toxicity and harmfulness reduction;
- bio-compatibility and resources conservation;

- product life optimization (extension and use intensification);
- material life extension;
- design for disassembly.

The last two principles of sustainable design presenting a more direct linkage with the production process are further described in the next paragraphs.

A *product with a longer lifespan* than another (having the same function) generally determines smaller environmental impact. If a product lasts a shorter time it not only generates waste prematurely, but also determines further indirect impact owing to the need to replace it. Production and distribution of a new product to replace its function involves the consumption of new resources and the further generation of emissions. In general, with regard to a product in use, the extension of its lifespan does not determine a reduction in impact; it may even happen that continuing to use an old product causes an increase in impact. If, for the same service provided, technological development offers the opportunity to have new products with better environmental effectiveness (lower consumption of energy or materials or reductions in emissions), the time will come when the need to manufacture, distribute and dispose of a new product will be compensated for, in terms of balancing environmental impact, by improved performance in use.

However, the duration of products can be planned by increasing their reliability and facilitating updating, adaptability, maintenance, repairs, reuse and re-manufacturing. Actually we can optimize the lifespan of products from the environmental point of view by intensifying their use: a number of people using the same product (or component) at different times. A product used more intensely than others leads to a reduction in the quantity of product present at a given time or in a given place in order to meet a given demand for a function; i.e. it determines a reduction in environmental impact.

In the case of *extending the lifespan of materials* it means in practice a design that valorizes material from scrapped products, which rather than ending up in landfills, can be reprocessed to obtain new secondary raw materials, or incinerated (burned) to recover their energy content. We use the term ‘recycling’ when secondary raw materials are used to manufacture new industrial products. On the other hand, when secondary raw materials are made into compost, we speak of composting. In all these cases the environmental advantage is double:

1. In the first place we avoid the environmental impact of disposing of materials in landfills.
2. In the second place resources (not virgin) are made available for the production of materials or energy which avoid the impact from the removal and production of a corresponding quantity of materials and energy from virgin natural resources. The impact of these avoided processes can be considered an indirect environmental advantage.

Design for the extension of the lifespan of materials does not mean simply choosing materials with efficient recycling or combustion technologies. We must facilitate all the stages of recycling (or composting or incineration), and design to facilitate collection and transport after use, identify materials, minimize the number of incompatible materials, facilitate separation of incompatible materials and facilitate their cleaning.

Design for disassembly: facilitating disassembly means design that aids the separation of parts (for maintenance, repairs, updating or reuse) or incompatible materials (to be recycled or from which to recover energy content). This strategy is therefore helpful for both product life extension and use intensification and material life extension.

Sustainable design has clearly a more broad perspective on waste than lean production. It starts with questioning if we really need to produce a new product/system and such questioning is not part of the lean production scope. Lean production is all about reducing waste and increasing value but when it defines value it always assumes that at a given point it will be materialized into a product/system. On sustainable design the provision of value (function) does not necessarily imply an actual production as it was described earlier in this paper. However, the theory of sustainable design is not sufficient to achieve a waste reduction at the production level since by focusing on the product it overlooks the waste on flow, both on operations (flow of people/machines) and processes (flow of material/information). Therefore, both areas have to work together in order to accomplish comprehensive reduction/elimination of waste.

RESEARCH METHOD

Case study is the main research strategy adopted in this study. It revisits data from a previous study carried out by the main author during his PhD (Santos 1999). It adopted Koskela’s (2002) theoretical framework and focused on only four of the lean construction principles proposed by that author: reduction of cycle time, reduction of variability, increase of transparency and build of continuous improvements. The analysis from a sustainable design point of view focused on the issue of material life extension, looking for evidence of practices with that objective.

The analysis uses a process called pattern matching where the researcher looked for direct replications of the theoretical propositions as described by Santos *et al*. (2001). In this process, the empirical evidence was considered to be a ‘literal replication’ when observed results matched the theoretical predictions (e.g. a visual control that contributes to facilitate measurements). In contrast, when the case study produced contrasting results but for predictable reasons, it was called a ‘theoretical replication’ (e.g. excessive measurement associated with a lack of visual controls).

Information obtained through quantitative and qualitative techniques was used to substantiate the pattern matching. Boundary searching on the typical values of key quantitative indicators contributed to the assessment of the empirical evidence and such information is available in the PhD thesis of the main author (Santos 1999).

RESULTS AND ANALYSIS

Looking at waste from a lean construction point of view

The host construction company of this case study was large (> 500 employees) and had offices all over England. The company won the contract for the site under observation after winning a bid based on the lowest price for construction. Communication with client, design management, subcontractors and supply management was the responsibility of a project manager. An experienced construction manager was also responsible for the actual daily management of all construction works.

The construction site was located in the city centre of Bradford and had an area of approximately 15 acres. At one end of the site there was a 103 000 sq. ft office development under construction that would serve as a regional office for another large company. At the other end of the site there was a retail building (105 000 sq. ft) and car parking for 600 vehicles, also under construction.

The data collection on this site concentrated on the bricklaying operating in the retail building. At the start of the data collection most of the steel structure was practically completed and painting had just been commenced. The roof fixation was around one-quarter of the total roof area. External walls, DPC and the slab had just started construction. Externally, there were many simultaneous activities being carried out such as drainage, roads and the foundations for the car park.

This case study revealed only a few 'literal replications' of lean construction heuristics and none of them had a satisfactory level of integration. The following items illustrate the status of waste observed in this case study:

- *Overproduction*: the paradigm of mass production among construction managers and workers was present in this case study. The volumes of 'transfer batches' were large and bricklayers started bricklaying operations in more workplaces than they could operate. The end result was large amounts of work-in-progress throughout the sites. Construction managers did not seem to agree that the use of resources in their full capacity, producing more sub-products than necessary was a waste of resources. In fact, for them waste due to overproduction does not appear to exist in construction since the parts of a project have to be produced anyway.
- *Inventory*: the literature shows that a good observational criterion to understand flows (and waste) on site is the amount of inventory available on site. The researcher decided to use an indicator to measure the 'flow efficiency' by linking the average storage of blocks/bricks to the rate of productivity. Ideally, the rate of deliveries of bricks/blocks should be closely linked to the production rate of bricklaying and, in this way, there should be no intermediate storage. The case study revealed five cubic metres of brick storage per bricklayer/day in the two weeks of investigation (flow efficiency = 0.05). The practice of large 'delivery batches' was worsened by the manager's decision to concentrate the blocks in a single storage area. The construction was large and the use of a single site storage area meant the need for long transportation distances. Furthermore, the large amount of blocks on site reduced transparency regarding the control of volumes and the position of machines.
- *Repair/rejects*: this company undertook no activity to find and eliminate the root cause of process problems during the period observed. The only poka-yoke device identified was a safety mechanism attached to transporting equipment. This safety mechanism produced a sound that alerted every time the equipment moved backwards. However, it had little impact on the actual reduction of variability since it had no direct effect on the main process problems and had been imposed from outside the site manager's control. This case showed very few activities relating to continuous improvement, a fundamental principle of lean production. The only clear positive practice resembling such principle was the maintenance of the same management team across different projects. This practice made the communication process easier

and led to better problem solving throughout the project, according to the interviews.

- *Motion/transport*: the lack of planning and coordination of flow among workstations resulted in an increase in transportation distances. This was because there were too many fronts of work operating at the same time, and these were spread in a large area in comparison with the number of bricklayers available.
- *Processing*: the observed process resulted in brick walls quite different from the specified result. However, the processing activities presented some lean practices that helped to reduce the problem. Visual controls, for instance, allowed bricklayers to identify vertical positions of the brickwork courses extremely quickly and, also, enabled them to accomplish their operations with more accuracy. Nevertheless, there were no visual controls to guide workers on the layout planning and workstation flow throughout the whole construction site. In addition, there was only one information area for the entire site and even that was out of the workforce's normal pathway. This lack of information for the workplace contributed to the lack of awareness among workers regarding schedule deadlines and standard procedures.
- *Waiting*: the high volume of work-in-progress added further complexity, reducing synchronization between suppliers and the workstations. This situation contributed to an increase in the amount of time spent on non-value-adding activities.

Everyday observations on the site also revealed that this company relied heavily on the intensive use of modern equipment and materials as the means of guaranteeing their objectives with respect to cost, delivery, quality and flexibility. However, the actions of managers revealed little concern with the potential gain achievable through the elimination of non-value-adding activities from production. In this respect, there was severe scepticism among the managers on this site with respect to the early involvement of subcontractors and their employees in continuous improvement activities.

The short-term basis of the relationship with subcontractors and the bonus system itself were also often pointed out as the major barrier for improving practices. Indeed, the contracting system itself did not favour the establishment of long-term relationships between subcontractor and contractor, since low price was the main winning criterion in the bidding process. Thus, as long as the subcontractor finished the job on time, under the budget and to the specified quality, there were no efforts from the contractor to push the process performance towards even higher levels.

Looking at waste from a sustainable design point of view

The analysis of the design of components with a focus on the issue of 'material life extension' revealed various weakness of the bricklaying process within this construction site. The analysis looked for literal replications of the heuristics proposed by Manzini and Vezzoli (2004). The main findings regarding what the observed process requires to improve its performance on material life extension are presented below.

A need for adopting a cascade approach for recycling

- The brick wall did not allow arranging and facilitating of the recycling of components that went into it and that presented lower/different mechanical and aesthetical requirements (wood, steel and bricks).
- The production process did not arrange and facilitate energy material recovery (for instance: contaminated cardboard packaging).

A need for selecting materials with more efficient recycling technologies

- The bricklaying process uses composite materials with inefficient recycling technology.
- It did not use ribbed and similar structures to improve rigidity of components.
- Some components for windows and doors used thermo-resistant polymers instead of flame retardant.

A need to facilitate the collection and transportation of waste

- The technology did not minimize weight.
- The technology presented poor compressibility of disposed product.
- The brick wall did not provide the end-user with information about disposal treatments.

A need for a better system for material identification

- The components did not present any code system to display their category.
- The components did not provide additional information about the age, the number of already occurred recycles and the additives used.
- No information about toxic or dangerous materials was provided in the packaging or component surfaces.

A need to minimize the number of incompatible materials and/or facilitate the separation

- There was more than one material within the bricklaying components and there were no use solutions such as homogeneous materials in sandwiching structures.
- There was a lack of connection systems made of the same, homogeneous or compatible materials with the components to be joined.

A need to facilitate cleaning

- The production process and the characteristics of components did not avoid unnecessary superficial treatments and it was difficult to remove contaminants.
- The brick wall finishings did not avoid adhesives.
- There was no code on the brick wall to direct cleaning activities.

A need to facilitate composting

- The production technology did not avoid non-degradable materials.
- This construction site lacked a system to use degradable materials for reverse logistic packaging.
- There was no system on the construction site to facilitate the separation of non-degradable materials.

- There was no system to avoid non-combustion retardant materials or avoid materials toxic in combustion or avoid additives toxic in combustion.
- There was no system to facilitate the separation of non-combustible materials.

A bridge between lean construction and sustainable design

This case study has revealed clear connections between lean construction and sustainable design with regard to waste. The major difference lay in the width of the sustainable design approach when compared to lean construction. Sustainable design looks beyond the production stage, including all phases that compose the material life cycle. On the other hand, lean production has a more consolidated set of tools and principles that one cannot find within the sustainable design literature. Rephrasing our previous argument: perhaps the most profound implications of these two different views of waste is the fact that lean production always assumes that production is necessary while sustainable design starts with the question: is there any alternative to avoid production such as sharing buildings/equipments/components and moving towards product-service systems?

A review of the construction components design and the implementation of a system that facilitates the identification, collection and transportation of waste, for instance, had a direct effect on the amount of non-value-adding time observed on the case study. A system for material identification, for instance, affects positively the 'reduction of variability' and 'increase of process transparency' within the production process, key principles of lean production, avoiding costly mistakes and waste of time with the search for information.

The implementation of a lean principle such as 'building continuous improvement into the process' provides the foundation to enable more effectiveness of sustainable design practices such as the 'cascade approach' for recycling. Without the proper involvement and commitment of workers the waste of construction process may not follow the ideal route designed by the cascade approach. Continuous improvement is also necessary to bring the knowledge of workers to support the identification of areas where it is difficult to separate one material from another or it is difficult to clean up.

CONCLUSIONS

The combined use of lean production heuristics and sustainable design expands the opportunities of reducing waste within production systems. Lean construction looks at actions that could reduce or eliminate waste out of the construction site. Sustainable design, on the other hand, when dealing with the production stage, would start by looking for alternative ways to avoid the production activity.

While lean construction would look solely into wastes such as overproduction, inventory, repair/rejects, motion, transport, processing and waiting, sustainable design will look at other sources of waste throughout the entire life cycle of a given construction component. Sustainable design can contribute to lean construction with solutions that enable material consumption reduction, energy consumption reduction, toxicity and harmfulness reduction, bio-compatibility and resources conservation, product life optimization, material life extension and design for disassembly, all of them with direct implications on the reduction of waste within the construction industry.

There are a limited number of construction professionals with knowledge and competencies to operate across both fields of knowledge and such gap presents an opportunity for construction researchers and professionals. A small but growing number of industries that used to deal with the issue of waste solely from a production management point of view are now realizing that sustainability must be integrated with the expected competencies of production managers. The authors believe that construction companies have to realize the importance of such integration since there is an increasing demand for ‘green and lean’ construction sites.

REFERENCES

Ballard, G and Howell, G (1998) What kind of production is construction? Paper presented at the Sixth Annual Conference of the International Group for Lean Construction (IGLC-6), 13–15 August 1998, Guarujá, Brazil.

Brezet, H and Hemel, C van (1997) *Ecodesign. A promising approach to sustainable production and consumption*. Paris: UNEP.

Charter, M and Tischner, U (2001) *Sustainable solutions, developing products and services for the future*. Sheffield: Greenleaf Publishing.

Dahlström, H (1999) Company-specific guidelines. *Journal of Sustainable Product Design*, January.

Formoso, C T, Isatto, E L and Hirota, E H (1999) *Method for waste control in the building industry. In*: I D Tommelein (Ed.) *Proceedings IGLC-7*, University of California, Berkeley, California, USA, 325–34.

Imai, M (1997) *Gemba Kaizen: a commonsense, low-cost approach to management*. McGraw-Hill.

Koskela, L. (1999) Management of production in construction: a theoretical view. *In*: I D Tommelein (Ed.) *Proceedings Seventh Annual Conference of the International Group for Lean Construction*, University of California, Berkeley, California, USA, 241–52.

Manzini, E and Vezzoli, C (2002) *O desenvolvimento de produtos sustentáveis. Os requisitos ambientais dos produtos industriais.* San Paolo: EDUSP.

Mont, O (2002) *Functional thinking: the role of functional sales and product service systems for a function-based society*, Report 5233. Stockholm: Naturvårdsverket.

Santos, A (1999) *Application of flow principles in the production management of construction sites*, PhD Thesis, School of Construction and Property Management, University of Salford, England.

Santos, A dos, Powell, J and Hinks, J (2001) Using pattern-matching for the international benchmarking of production practices. *Benchmarking: An International Journal*.

Shingo, S (1989) *A study of the Toyota production system from an industrial point of view*. Trans. A P Dillon. Productivity Press.

Vezzoli, C (1999) An overview of life cycle design and information technology tools. *Journal of Sustainable Product Development*, **9**, 27–35.

Vezzoli, C (2003) Designing systemic innovation for sustainability. University of Arts and Design Helsinki, Helsinki, Cumulus Working Papers Tallinn, 21–31.

Yin, R K (1994) *Case study research: design and methods*. 2ed. Thousand Oaks, CA: Sage Publications.

CONSTRUCTION JOB SAFETY ANALYSIS IN SUPPORT OF LEAN PROJECT MANAGEMENT

Ophir Rozenfeld[1], Rafael Sacks,[1] Yehiel Rosenfeld[1] and Hadassa Baum[2]

[1]*Faculty of Civil and Env. Eng., Technion – Israel Institute of Technology, Haifa 32000, Israel*
[2]*National Building Research Institute, Technion – Israel Institute of Technology, Haifa, 32000, Israel*

Job Safety Analysis (JSA), which is also known as Job Hazard Analysis, is an efficient proactive measure for safety risk assessment used in industrial manufacturing settings. However, unlike the manufacturing settings for which JSA was developed, in construction sites the physical environment is constantly changing, workers move through the site in the course of their work, and workers are often endangered by activities performed by other teams. To address this difficulty, a method specialized for construction has been developed, called "Construction Job Safety Analysis" (CJSA). The CJSA method was developed within the framework of research toward a lean approach to safety management in construction, which required the ability to predict fluctuating risk levels in order to support safety conscious planning and pulling of safety management efforts to the times and places in which they can be most effective. The method involves identification of potential loss of control events for detailed stages of the sub-activities commonly performed in construction, and assessment of the probability of occurrence for each event identified. The method was applied to explore 14 primary construction activities. A survey was conducted through some 100 interviews with site managers and safety experts to reveal the likelihood of loss of control events that may lead to accidents. Detailed quantitative results were obtained for 699 such events. The most frequent events are those related to exterior work at heights.

Keywords: construction planning, health and safety, lean construction, risk identification.

INTRODUCTION

In almost every country in the world, the construction industry stands out among all other industries with disproportionate numbers of severe and fatal accidents (Ahmed *et al*. 2000; Findley *et al*. 2004; Gyi *et al*. 1999; Kartam and Bouz 1998; Shepherd *et al*. 2000; Stanton and Willenbrock 1990). Construction projects are dynamic (Bobick 2004) and involve many unique factors such as frequent work team rotations, exposure to weather conditions, high rates of unskilled workers, and more, that make managing construction site safety more difficult than managing safety in manufacturing plants. A construction site, unlike other production facilities that people work in, undergoes changes in topography, topology and work conditions over time throughout the duration of the construction project and, therefore, it requires a different safety management approach in order to identify risks, increase safety and prevent accidents.

Applying lean thinking (Womack and Jones 2003) to construction in this context leads to the hypothesis that, like production control itself, activities to enhance safety should

[1] ophirr@technion.ac.il

be pulled by current system needs rather than pushed uniformly onto workers and activities. The CHASTE (Construction Hazard Assessment with Spatial and Temporal Exposure) approach (Rosenfeld *et al*. 2006) has been developed to implement and test this hypothesis. The basic idea is that although construction projects as a whole are unique and dynamic, individual construction tasks and methods are fairly well-defined and expected. For example, pouring concrete using a crane on site is a common well-understood trade activity, but the level of risk associated with it can differ from one site to another. At one site, it may be performed at the end of the day when no other tasks are being performed, while at another it might be performed at the middle of the day when many other workers are located either on or below the element being cast.

By separating the potential for loss of control from the potential for presence of victims, it becomes possible to compute a time-dependent risk level forecast, using a database of probabilities of loss of control for standard work methods, coupled with site-specific computation of workers' exposure to the possible loss of control events. The result is a more accurate assessment of actual risks than is available using current methods, such as Preliminary Hazard Analysis (PHA) (Elzarka *et al*. 1995; Hansen 1993; Saurin *et al*. 2004). The predicted risk levels can be computed for various planning windows and used either to pull safety interventions or to change production plans, both of which enhance safety. Thus, management efforts to enhance safety can be less wasteful and more effective.

For many reasons, statistical approaches based on historic accident data are unsuitable for predicting risk levels in construction in order to compile the trade method risk database. Numerous factors affect safety, directly and indirectly, producing very large combinatorial numbers of possible accident events. The number of documented accidents is many orders of magnitude smaller than the number of possible accident events. For every serious construction accident, there are multiple actual dangerous events that end with no injury (Lyachin 2004). Hence, and in addition to the fact that most accidents that result in less than ten days of absence are rarely reported, the aggregated statistics-based approach is not a suitable forecast tool for the prediction of loss-of-control events at any particular place during a particular time frame.

To overcome this problem, a different conceptual approach is required. The risk level is divided into four parameters: the probability of a loss of control event occurring, the exposure of potential victims in time and in space, and the likely severity level of an accident (which is also dependent on the use of personal safety equipment). To do this, knowledge of construction activity types is needed, including the nature and probability of loss of control events, the impact of environmental intensifying factors, the use of protective equipment, and the potential severity of accident events. Each of these must be compiled in a knowledge base in a form that can be used by the CHASTE method software to compute risk levels for specific construction projects. The following sections describe the method devised to collect this information and provide examples of the results of its application in the Israeli construction industry.

METHODOLOGY

CJSA – Construction Job Safety Analysis

Job Safety Analysis (JSA, also known as Job Hazard Analysis (JHA) is a practical method for identifying, evaluating and controlling risks in industrial procedures. The process of JSA includes three main stages (Chao and Henshaw 2002):

1. Identification – choosing a specific job or activity and breaking it down into a sequence of stages, and then, identifying all possible loss of control incident that may occur during the work.
2. Assessment – evaluating the relative level of risk for all the identified incidents.
3. Action – controlling the risk by taking sufficient measures to reduce or eliminate it.

For determining a priority order of treatment, the level of each incident risk is evaluated by assessing the incident's probability of occurrence and its most expected outcome (the level of injury). Those two measures place the risk in a standard scale from most negligible to the most severe.

The JSA method has proven to be efficient for planning the safest way to perform any task (Holt 2001). However, in its current form, it is impractical for the construction industry. Unlike other industries, construction projects are highly dynamic, the production environment changes in time and place, and work crews change frequently. Moreover, construction products are unique, and most of the time performed as a prototype; standardized procedures that may be considered safe in one project may be hazardous in the environment of a different project. Another drawback of the traditional JSA is that in construction, workers commonly endanger other workers, who may be performing a different activity at a different location. The regular JSA is not designed to reveal these dangers since it focuses on production activities in isolation, at predetermined workstations.

For these reasons, a different approach is needed for construction. This research proposes an improved technique, called Construction Job Safety Analysis (CJSA), in which the job analysis is performed independently of any specific consideration of time and place. This is achieved by separating the loss of control that precedes any accident from the potential presence of a victim in the path of harm. Loss of control events are assessed in the CJSA, which is generic across any local construction industry, while exposure of victims in time and space is assessed for specific construction projects (for details, see Sacks *et al*. 2007).

The CJSA method generates a large knowledge-base describing all possible loss of control events in construction; the database is then used by the CHASTE software system (Sacks *et al*. 2007) to compute the predicted risk levels for the activities of specific projects, using their physical layout and their planned schedule.

CJSA step 1 – identification

In the first step of the CJSA method, standard construction methods are identified and detailed. The procedure for each method consists of:

1. Breaking the activity down into sub activities and determining their expected start and finish times relative to the timeline for the whole activity as it would be represented in a construction plan. These times are expressed in percentage terms, but may extend below 0% and above 100% where preparation or clean-up actions are needed that are generally not scheduled explicitly.
2. Breaking the sub activities down into work stages and determining their location type, crew composition and the total time proportion of each stage within each sub activity. The time proportions need not represent continuous execution of the stage, nor need they be exclusive at any given time.

3. Identifying all possible loss of control events during each work stage and determining their zones of influence and type.

Unlike in fixed plants, in construction, a hazard will often endanger workers other than those performing the task. Therefore, information concerning the most likely timing and location of each worker during each activity must be collected. The logical relationship between the location in which an activity is performed to other locations where victims may be present (such as 'adjacent', 'below', 'above'), are also needed. Figure 1 illustrates the hierarchic structure of an activity analysis.

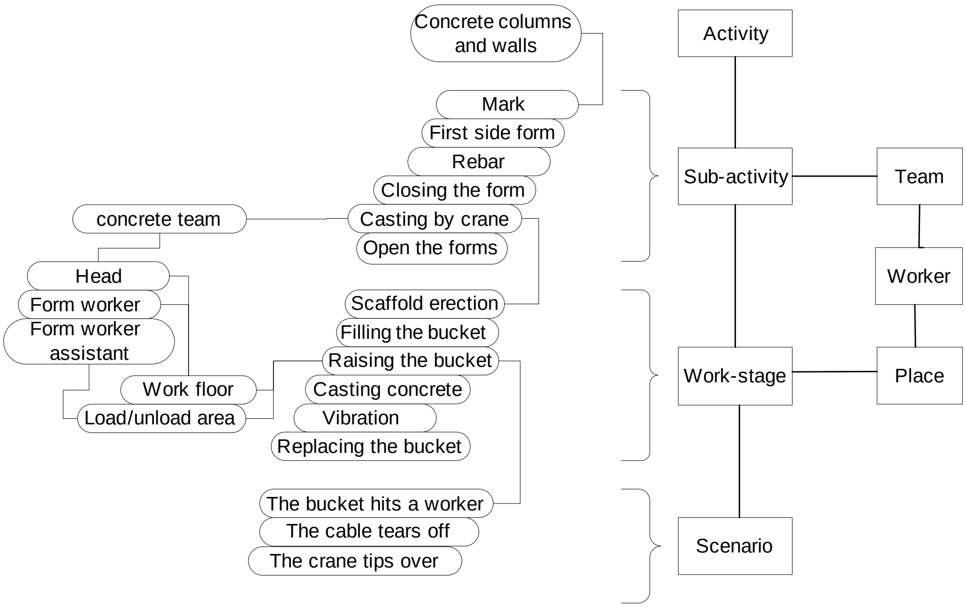


Figure 1: Information items defined in the knowledge base, relationships and examples

Step 2 – Assessment

The second step of the CJSA seeks to determine the following information about the activities that were detailed in the first step, all of which is essential for the functioning of the CHASTE model:

1. The expected rate of occurrence for each possible loss of control event as defined in the CJSA.
2. The degree of influence of the different managerial and environmental factors that affect the expected rates of occurrence.
3. The expected degree of use of personal safety equipment.

The information is collected by means of a survey, conducted through face-to-face interviews with construction superintendents. The survey instrument is a set of structured questionnaires that are produced automatically from the database of activities, sub-activities, stages, typical loss of control events, and their associated data, compiled in the previous CJSA step.

The survey is conducted among construction superintendents because they are the most appropriate source for practical information about potential loss of control events. Firstly, due to their key role in the practical execution of the work, they, more than anybody else, are aware of the overall circumstances on site: the composition of activities on site and their nature, the types of activities, the number of workers involved, equipment in use, organizational conditions, etc. Secondly, they are formally responsible for all safety issues on site and are involved in the investigations that follow any incidents, whether accidents or near misses.

Every respondent is asked to assess the frequency of all loss of control event occurrences during that single activity from the questionnaires with which they are most familiar. Each respondent is asked to provide both a numeric and a linguistic estimate of the likelihood of each of the set of loss of control events for the construction activity about which they are interviewed. The numeric response consists of two values: a number and the appropriate unit of time (for example, three times a month, once a year, twice a week, etc.). The linguistic response offers a scale from 1 to 5, where: 1 - has never occurred in my experience but is technically possible, 2 - occurs rarely, 3 - occurs seldom, 4 - occurs frequently, and 5 - occurs daily.

For each work stage, they are also asked to state the size of an average team and the influence of four intensifying factors on the occurrence rates. The team size is needed because each interviewee implicitly assesses the likelihood of occurrence for a specific team size he or she has in mind; the value assumed is essential in order to normalize the results across the survey and for later application to projects in which work teams may be of different sizes.

There are many factors that affect the safety level directly and indirectly, and they vary from one site to another. They include the record of safety training on the job-site, the company's safety culture, use of safety equipment, conditions of the work environment, weather, workers' experience, work-load pressure, the construction activity method and equipment, and more. Many researchers have tested the influence of specific factors, or groups of factors, on the rate of the accident occurrence (Hide *et al*. 2003; Hinze and Raboud 1988).

The final aspect tested for in the CJSA is the expected degree of use of personal safety equipment, including helmets, appropriate working shoes, gloves, safety harnesses and safety goggles during each particular activity.. This information is needed for the CHASTE model, because the model assumes that the degree of severity of injury resulting from any possible accident will be distributed differently depending on the victim's use of personal safety equipment. The expected severity outcome for any event is the weighted average of the two severity distributions that result when safety equipment is used and when it is not used.

TRIAL IMPLEMENTATION

Step 1 – identification

In the CJSA application for the CHASTE research project, the knowledge was elicited in a series of workshops with safety experts and senior site managers, who are legally responsible for site-safety. Each expert was asked to analyse a single construction activity according to his or her experience. For practical reasons, the research focused on just 14 common construction activities from all phases of a typical multi story building project. The activities were chosen and presented to experienced site managers and safety experts during the workshops. They were asked to analyse them as generally as possible, i.e. by trying to reflect the general construction industry rather than any single project or site.

The results of the workshop are summarized in Table 1. The electrical, plumbing and HVAC instillations are performed during all the project stages, and therefore, they were not considered as activities but scattered as sub-activities among other main activities. Finally, after sorting, filtering and dismissing repetitive data, 699 different possible loss of control events were defined for the 14 construction activities.

Sorting all the possible event events according to event type (Table 2) shows that the most common event types identified by the experts were "Fall from height", "Collision", and "Objects falling to the ground".

Table 1: Activity analysis summary (Rosenfeld *et al*. 2006)

Activity analysis summary				
Number of loss-of-control events	**Number of stages**	**Interviewee specialization**	**Activity**	
57	23	Superintendent	Piling	Foundations
85	22	Superintendent	Concrete slabs	Structural activities
74	28	Superintendent Safety inspector	Cast-in-place concrete columns and walls	
59	23	Superintendent	Erecting precast slabs	
57	23	Superintendent	Erecting precast walls	
67	24	Superintendent	Forming walls with stone cladding	
33	12	Superintendent	Brick masonry	Finishing activities
32	14	Superintendent Stone contractor	Stone cladding	
62	27	Superintendent	Exterior plastering	
25	14	Finishing foreman	Gypsum boards	
19	12	Finishing foreman	Floor tiling	
47	17	Sealing contractor	Roof sealing	
46	11	Glazing contractor	Glazing	
75	23	Electrical engineer	Electrical installation*	
57	29	Plumbing engineer	Plumbing*	
80	46	A.C. engineer	HVAC installation*	
875	**348**		**Total:**	

*Activities that are interlaced within other activities.

Table 2: Number of events according to event type

Number of appearances	**Event type**
186	Fall from height
102	Collision
52	Falling object towards ground
42	Falling object from crane
39	Collapse
35	Falling object inside work platform
31	Run over
31	Trapped
28	Crane collapse
28	Collision with transported material
25	Splashing material
22	Electrocution
20	Slipping
19	Falling object - self impact
14	Mechanical equipment collapse
13	Burn and toxic inhalation
12	Floor collapse
699	Total

Step 2 – assessment

In the CJSA implementation for the CHASTE research project, the population for the survey consisted of 91 senior superintendents from 45 construction companies. The majority were interviewed in depth about a single construction activity type. A small number of them were interviewed twice, because they were familiar with more than one activity type; a total of 101 interviews were conducted. The questionnaires collected were filtered by comparing the separate linguistic and numeric responses of each interviewee to the same questions, and by examining whether the responses were logical and complete. Of the 101 interviews, 14 were rejected, leaving 87 valid complete questionnaires.

The respondents' average period of construction experience was 21.8 years. In terms of company size, 44% were employed in small firms (up to 50 employees), 21% in medium-sized firms (51 to 100 employees), 5% in big firms (101 to 200 employees), and 30% worked for very large firms (over 201 employees). A total of 7% of the respondents were working on small projects (up to 1,500m^2), 61% on medium-sized projects (1,500 to 7,500m^2), 21% on medium-large projects (7,500 to 15,000m^2), and 11% worked on large projects (over 15,000m^2).

Likelihood of loss-of-control event occurrences

Average values for likelihood of occurrence for all loss of control events were summarized in measures of number of events per year of work per person, i.e. the expected number of times a single event might occur if a single worker performs a single task for a time period of one year. Table 3 lists five events out of the total 699 events that could arise from the 14 construction activities covered in the survey, ranging from the most frequent and to the most infrequent.

The recorded knowledge from the expert workshops included data about the proportional duration of every work stage for each sub-activity. The start and finish times of the sub- activities are available from the activity schedule of any construction project, and so the duration of each work stage can be determined. Multiplying the duration of any stage by the average event frequency and the number of workers in the work group gives the number of event occurrences expected for the stage, during any given period of activity.

Table 3: Five examples of event likelihood including the most frequent and infrequent loss-of-control events

Activity	Sub-activity	Stage	Event	Average likelihood (occurrences per worker per year)
Cast-in-place concrete walls with stone cladding	Pouring concrete using a crane bucket	Filling bucket	Concrete spatter	168.0
Cast lightweight concrete for drainage	Casting the concrete	Transporting concrete	Dropping an object	91.3
Gypsum boards	Erecting the framing	Attaching studs to exterior walls	Hit by ricochet	56.4
Exterior plastering	Manually applying an insulating layer	Curing	Hit by a tool	1.25
Concrete columns and walls	Casting concrete with a crane	Lifting a bucket full of concrete	Crane collapse	0.01

To compare the results of the survey between different activities and types of events, the likelihood of events was estimated for all loss of control events and for all of the 14 activities as if they were carried out continuously for one year. The expected number of events for each activity is shown in Figure 2. The most hazardous activity in terms of expected number of event occurrences is the application of exterior plastering, with 704 expected event occurrences for a single worker over a year (this is equivalent to a single plasterer causing an average of two loss of control events a day) which mostly result from the most commonly expected event type, that is 'dropping an object to ground level'. This event type is very common when working on an open scaffold and generated mostly during 'Exterior plastering' and 'Stone cladding' activities. As can be seen, activities with high levels of occurrence are those performed outside and at height, whilst activities performed indoors have relatively low levels of occurrence. The least frequent event type is 'floor collapse', which according to the interviewees is expected to occur once in ten years of continuous work. Although it is very rare, the expected outcome of this event is disastrous and therefore, it is a significant risk.

Intensifying factors
Implementation of the CJSA assessment step included examination of factors affecting the expected likelihood of occurrence of loss of control events. The respondents were asked to assess, based on their past experience, how the likelihood of lost of control events occurrence would be increased during each work stage of the entire activity, in the presence of the intensifying factors identified in the first step.

The influence of four intensifying factors on various activities was explored in the Israeli construction industry. The results are shown in Figure 3. The most significant intensifying factor was found to be a "worker's first day on site", followed by "crowding in work areas", "schedule delays" and "short notice before work" was to be performed. Interestingly, the management related factors were found to be more significant than the environmental factors.

CONCLUSIONS

The CHASTE approach represents a progressive way to evaluate risks in construction, which tries to confront the difficulties and uniquely hazardous nature of the construction industry. The associated CJSA method provides a mechanism for collecting the extensive knowledge of the likelihood of loss of control events in construction that is needed for implementation of the CHASTE method. The CJSA method is loosely based on the standard JSA approach to safety planning in manufacturing; it covers the first two stages of traditional JSA (identification and assessment), but does not extend to the ‘action’ stage.

The CJSA method described was implemented for the construction activities and methods typical of the Israeli construction industry, and a comprehensive analysis was conducted of its results. A number of lessons were learned from its implementation:

- The method is tractable, despite the large number of individual loss of control events that must be explored. Each interviewee was able to respond to up to 85 events within two hours.

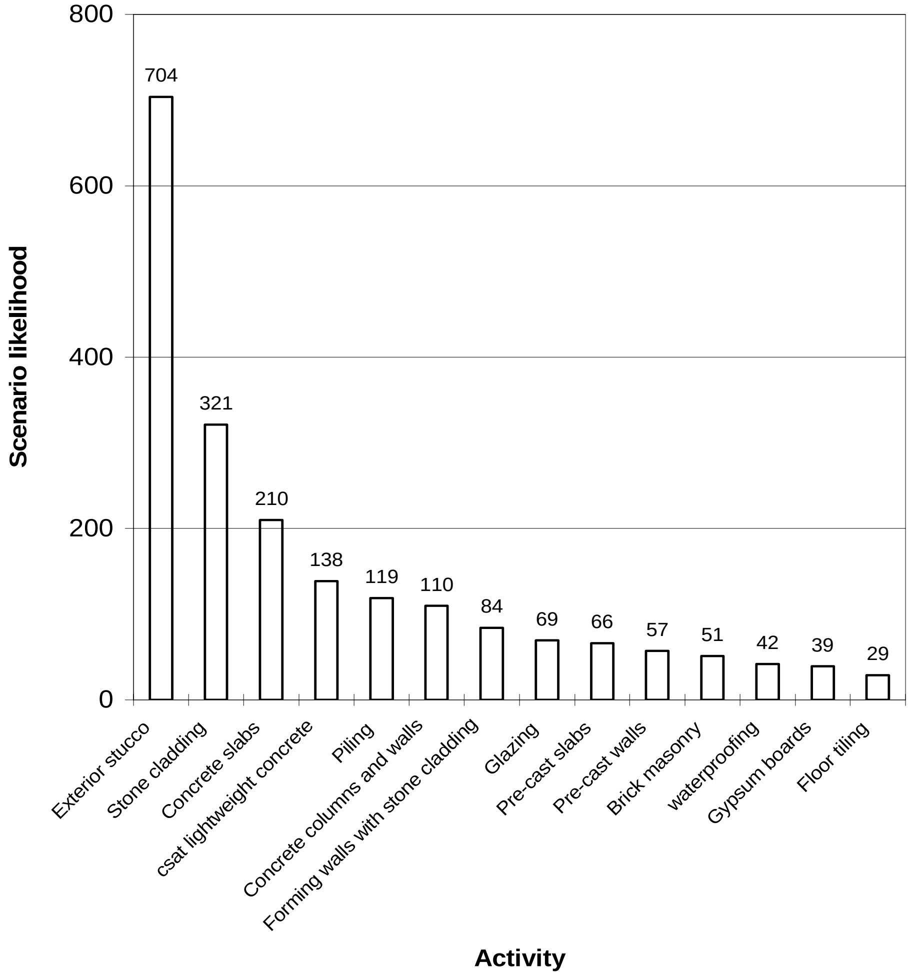


Figure 2: Number of event occurrences during a year of work according to activity type

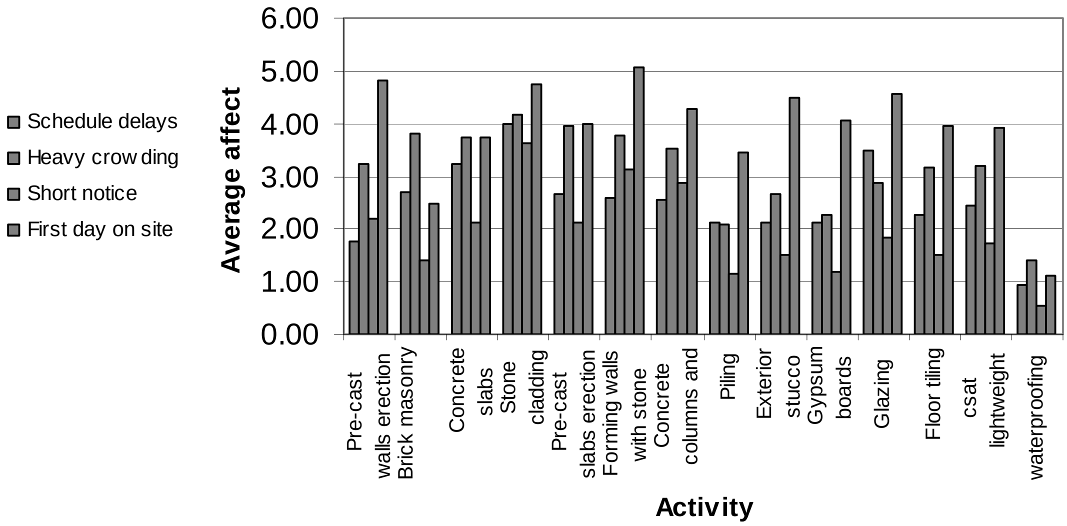


Figure 3: Average influence of intensifying factors on activity

- The need to obtain measures of likelihood of loss of control events, rather than of accident occurrence, meant that the interviewers had to explain the principle to each interviewee thoroughly in order to avoid responses based on misconceptions.

The major contribution of the CJSA method is that relative quantitative measures for each event are obtained. This information is essential to implementation of the CHASTE approach. Not surprisingly, the activities with the highest likelihoods of loss of control events were those performed outdoors and at height.

Research on the CHASTE approach is continuing with development of a computer application to predict risk levels for different work teams on sites as construction progresses. The approach as a whole will be tested on two projects. The focus will be on establishing effective ways of reporting the risk levels to site superintendents and managers, and on determining how they can use the predictions generated to pull safety management activities appropriately to where they are needed, or to change construction plans and schedules to avoid peak risk levels.

ACKNOWLEDGEMENT

This research was funded in part by the Ministry of Industry, Trade and Occupation under grant No. 2005902. The authors are also grateful to the Israeli Society for Occupational Safety and Health for their participation in the CJSA survey.

REFERENCES

Ahmed, S M, Kwan, J C, Ming, F Y W and Ho, D C P (2000) Site safety management in Hong Kong. *Journal of Management in Engineering*, **November**, 34–42.

Bobick, T G (2004) Falls through roof and floor openings and surfaces, including skylights: 1992–2000. *Journal of Construction Engineering and Management, ASCE*, **130**(6), 895–907.

Chao, E L and Henshaw, J L (2002) *Job Hazard Analysis*, OSHA, Occupational Safety and Health Administration, US Department of Labor.

Elzarka, H M, Minkarah, I A and Pulikal, R (1995) A knowledge-based approach for automating construction safety management. *Computing in Civil Engineering*, **2**, 997–1002.

Findley, M, Smith, S, Kress, T, Petty, G and Enoch, K (2004) Safety program elements in construction. *Professional Safety*, **49**, 14–22.

Gyi, D E, Gibb, A G F and Haslam, R A (1999) The quality of accident and health data in the construction industry: interviews with senior managers. *Construction Management and Economics*, **17**, 197–204.

Hansen, L (1993) Safety management: A call for (r)evolution. *Professional Safety*, **38**(3), 16–21.

Hide, S, Atkinson, S, Pavitt, T, Haslam, R, Gibb, A, Gyi, D, Duff, R and Suraji, A (2003) *Causal factors in construction accidents. 156*, Manchester Centre for Civil and Construction Engineering, Manchester.

Hinze, J and Raboud, P (1988) Safety on large building construction projects. *Journal of Construction Engineering and Management, ASCE*, **114**(2), 286–93.

Holt, A S J (2001) *Principles of construction safety*. London: Blackwell Science.

Kartam, N A and Bouz, R G (1998) Fatalities and injuries in the Kuwaiti construction industry. *Accident Analysis and Prevention*, **30**(6), 805–14.

Lyachin, B (2004) *Detection and analysis of safety hazards at construction sites with tower cranes*, MSc Technion - Israel Institute of Technology, Haifa.

Rosenfeld, Y, Rozenfeld, O and Sacks, R (1999) Efficient and timely use of safety resources in construction. *In: CIBW99, International Conference on Global Unity for Safety & Health in Construction*, Beijing, China.

Sacks, R, Rozenfeld, O and Rosenfeld, Y (2007) *Computing spatial and temporal exposure to safety hazards in construction*, Interim Research Report, National Building Research Institute, Technion, Haifa.

Saurin, T A, Formoso, C T and Guimaraes, L B M (2004) Safety and production: an integrated planning and control model. *Construction Management and Economics*, **22**, 159–69.

Shepherd, G W, Kahler, R J and Cross, J (2000) Crane fatalities - a taxonomic analysis. *Safety Science*, **36**, 83–93.

Stanton, W A and Willenbrock, J H (1990) Conceptual framework for computer-based construction safety control. *Journal of Construction Engineering and Management, ASCE*, **116**(3), 383–98.

Womack, J P and Jones, D T (2003) *Lean thinking: Banish waste and create wealth in your corporation*. New York: Free Press.

PREVAILING WAGE LAWS, PRODUCTIVITY AND CONSTRUCTION EFFICIENCY

Kevin Duncan,[1] Peter Philips[2] and Mark Prus[3]

[1]*Hasan School of Business, Colorado State University-Pueblo, Pueblo, CO 81001, USA*
[2]*Department of Economics, University of Utah, Salt Lake City, Utah 84112, USA*
[3]*School of Arts and Sciences, State University of New York, Cortland, NY 13045, USA*

Stochastic frontier regression is used to conduct a direct test of prevailing wage legislation on school construction efficiency. The efficiency of projects covered by the introductory stage of British Columbia's construction wage legislation, relative to the best-practice production frontier, was 9% lower than other, uncovered, projects. However, by the time of the expansion of the policy 17 months later, the efficiency of covered projects increased by 32%. These findings suggest that the introduction of prevailing wage laws disrupted construction efficiency. However, in a relatively short period of time, the construction industry adjusted to wage requirements by increasing overall efficiency.

Keywords: building regulation, productivity, econometrics.

INTRODUCTION

Prevailing wage laws require contractors of covered public projects to pay construction workers what some observers call 'super minimum wages'. This paper examines the impact of this legislation on the efficiency of construction. Others cite country-specific examples of construction industry adjustments to general increases in wages that include the increased use of industrial methods in construction, the substitution of skilled for unskilled labour and the substitution of capital for all grades of construction labour (see Risager 1993; Tan 1996; Warszawski 1990). However, these studies do not report an estimate of the total effect of these changes on the efficiency of construction, nor do they address the impact of legislated wage changes. These issues are relevant because they provide insight into the debate regarding the cost impact of prevailing wage laws. For example, Dunn *et al*. (2005) estimate that prevailing wage requirements increase the cost of covered housing projects from 9% to 38%. This finding is consistent with the view that prevailing wages are associated with less efficient, more costly construction. However, Duncan and Prus (2005) fail to find a statistically significant prevailing wage cost effect. This result implies substantial productivity changes that offset the cost implications of prevailing wages.

Elsewhere we have examined the impact of prevailing wage regulations on efficiency through an examination of construction output (see Duncan *et al*. 2006). We find that prior to the introduction of prevailing wage requirements, publicly funded school projects were from 16–19% smaller, in terms of project square feet, than comparable privately funded projects. This size differential did not change after the introduction of the wage policy. This finding suggests that wage requirements did not alter input

[1] kevin.duncan@colostate-pueblo.edu

utilization in a way that significantly affected the technical efficiency of construction, when efficiency is viewed as the ability to produce surface area. In this follow-up to our previous research, we conduct a different, more direct test of the impact of prevailing wage regulations on the efficiency of construction. Our previous analysis used stochastic frontier regression to estimate construction output, project square feet, as a function of the total input bill (bid price) and wage policy variables. In the present study, we use another variant of stochastic frontier regression to obtain project-specific measures of technical inefficiency or deviations from the best-practice production frontier. We then test if deviations from the production frontier are systematically related to the prevailing wage policy. In a sense, this is a more direct test of prevailing wages on construction efficiency since we examine the impact on measures of inefficiency instead of project size. Specifically, we use the inefficiency measures to examine the effect of British Columbia's Skills Development and Fair Wage Policy (hereinafter, SDFW) on the productive inefficiency of covered projects, relative to projects that were unaffected by the policy. Since the SDFW was introduced in two stages over time, our data allow us to examine the initial impact of the policy on technical inefficiency, as well as the impact after contractors have acquired experience with wage requirements.

THE SKILLS DEVELOPMENT AND FAIR WAGE POLICY

The Province of British Columbia introduced the first stage of the SDFW on 30 March 1992. Initially, the policy applied to building construction, with a value of at least CA$1.5 million that was funded by the Province. The second stage of the policy was introduced on 20 August 1993 with the value threshold reduced to CA$250,000 and coverage extended to other provincially funded projects (roads, dams, etc.). The skills development aspect of the policy sought to increase apprenticeship participation by requiring certified trades persons to supervise apprentices on covered projects. The policy also established the Schedule for Fair Wage Minimum Hourly Rates for construction workers employed on projects covered by either stage of the SDFW. This schedule ranged from 82% to 94%, but typically 88%, of the corresponding building trade union rate for specific construction occupations (see Globerman *et al*. 1993). Consequently, fair wage rates only applied to non-union contractors since union rates exceeded the minimums. We use the method developed by Thieblot (1995) to compare the strength of the SDFW to state-level prevailing wage legislation in the US. Based on a 2–17-point scale, the SDFW has a point total of 13. This compares to a weighted state average of 9.77. This indicates that the SDFW was above average in terms of strength, compared to legislation in the US.

DATA AND MODEL

School construction data were obtained from Canadata, an organization that collects and disseminates detailed data on the Canadian construction industry. Our sub-sample consists of 438 public K-12 school projects built between 1989 and 1995 and is used to test the impact of both stages of the SDFW on construction inefficiency.

We use stochastic frontier regression to estimate the best-practice construction frontier in our sample and to obtain the observation-specific measures of technical inefficiency. Stochastic frontier regression involves the estimation of a production function with an error term consisting of two components (see Aigner *et al*. 1977). The first component (v) is the standard, two-sided, random component with mean zero and variance σ_v^2. The second component (u) is a one-sided, non-negative, random variable with variance σ_u^2 that is assumed to be greater than zero. The value of *u*, ranging from 0 to 1.0, represents the observed level of inefficiency for a producer relative to the best-practice production frontier derived from the sample. Therefore, *u* measures the deviation of observed output from the production frontier. Like v, a value of *u* is estimated for each observation in the sample. The usual independence assumptions apply to each of the error components. Each is assumed to be independent of the other and of the independent variables in the equation. There is no theoretical rationale for the particular distribution of *u*. The results reported below are based on a truncated normal distribution. To avoid violating these error term independence assumptions, we use the FRONTIER 4.1 program described by Coelli (1996) to estimate the single-stage stochastic frontier and inefficiency models described below.

Stochastic Frontier Model:

$Ln\ Project\ Square\ Feet = \beta_0 + \beta_1\ Ln\ Real\ Bid\ Price + \beta_2\ X + (v - u)$

Inefficiency Model:

$u = \ast_0 + \ast_1\ SDFW_{92}\ Project + \ast_2\ SDFW_{93}\ Project$

where *Ln Project Square Feet* (in the Stochastic Frontier Model) is the natural log of a project's number of square feet and is our measure of construction output. *Ln Real Bid Price* is the log of a project's bid price and is our measure of inputs used in construction. We use the Non-Residential Building Cost Price Index available from Statistics Canada to adjust bid prices for inflation. *X* is a vector of project characteristics that are related to construction output. This vector includes the log of the number of stories above ground, a distinction between new construction and additions, where the project was located, and the time of year, and year, the project started. The error terms are *v* and *u*, as described above.

In the inefficiency model, *u*, the measure of construction inefficiency, is the dependent variable. As mentioned above, *u* may range from 0 to 1.0. $SDFW_{92}$ *Project* is equal to one if the public school was built during the first stage of the SDFW (between 30 March 1992 and 19 August 1993, with a value greater than CA$1.5 million), else zero. $SDFW_{93}$ *Project* is equal to one if the public school project was built during the second stage of the policy (after 19 August 1993 with a value greater than CA$250,000), else zero. The coefficients for $SDFW_{92}$ *Project* and $SDFW_{93}$ *Project* ($\ast_2$ and $\ast_3$) measure the inefficiency differential between projects covered, and not covered, by the SDFW. Negative estimates of $\ast_2$ or $\ast_3$ indicate that, after the introduction of the particular SDFW policy stage, covered public school projects were relatively less inefficient (more efficient) than projects not affected by this stage of the policy. Positive values for these coefficients indicate relatively higher inefficiency for covered projects. We have described above the possible positive and negative impacts of the SDFW on technical efficiency and construction costs. Given the bone of contention between these two possibilities, and the strong a priori expectations, two one-tailed tests are preferred to a single two-tailed test for these coefficients.

EMPIRICAL RESULTS

Summary statistics for all public school projects and those covered by each stage of the SDFW are reported in Table 1. Our sample consists of 438 public school construction projects. The nominal bid prices for these projects range from CA$58,700 to CA$31.1 million. Since this range falls below the value thresholds of either stage of the SDFW, our sample contains public projects that were not covered by the policy because they did not meet the value threshold, or because they were built prior to the fair wage regulations. The sample contains 243 projects that were not covered by the SDFW. Seventy-four of the projects were covered by the first stage of the policy (if $SDFW_{92}$ *Project* equals 1). A total of 121 were covered by the second stage (if $SDFW_{93}$ *Project* equals 1).

Table 1: Summary statistics for public school construction, British Columbia, 1989–1995

Variable	**All Public Schools Mean**	**$SDFW_{92}$ Projects Mean**	**$SDFW_{93}$ Projects Mean**
Ln Square Feet	9.413	10.109[a]	9.576
	(1.08)	(0.72)	(1.05)
Square Feet	[21,923f^2, 2,038m^2]	[31,973f^2, 2,970m^2]	[24,760f^2, 2,300m^2]
Ln Real Bid Price	14.062	14.982[a]	14.259
	(1.19)	(0.63)	(1.08)
Real Bid Price	[CA$2,486,807]	[CA$4,024,302]	[CA$2,780,428]
Ln Stories	0.126 [1.2]	0.212[a] [1.3]	0.150 [1.2]
	(0.28)	(0.33)	(0.30)
Vancouver	0.349	0.311[a]	0.339[a]
	(0.02)	(0.06)	(0.05)
Addition	0.651	0.527[a]	0.603[a]
	(0.02)	(0.06)	(0.05)
Wet Season	0.272	0.284	0.240[a]
	(0.02)	(0.06)	(0.05)
N =	438	74	121

Source: Canadata, 1989 to 1995. Standard deviations in parentheses (deviations for dummy variables are the standard deviations of the sample proportion). Conversions for square feet, square metres, Canadian dollars and number of stories in brackets. [a]The mean for $SDFW_t$ Projects is different at the 0.05 level from the comparable mean for All Public Schools.

The averages indicate that only projects covered by the 1992 provisions of the SDFW are larger, more expensive and have more storeys when compared to the overall sample of school projects. These differences for the 1992 projects are significant at the 0.05 level. Projects covered by either stage of the policy are less likely to be built in Vancouver and to be additions. Projects covered by the 1993 provisions are less likely to be started during the high precipitation months of December through March. These differences are statistically significant at the 0.05 level.

Since our primary interest involves the effect of fair wage requirements on construction efficiency, we focus first on the results of the inefficiency model. These results are reported in Table 2 under 'Inefficiency Estimates' (columns 3 and 4). The coefficient for $SDFW_{92}$ *Project* is positive and significant at the 0.10 level (for a one-tailed test). This finding indicates that the construction of the 74 public projects covered by the first stage of the SDFW (from 30 March 1992 to 19 August 1993) was relatively less efficient, by about 9 percentage points, than other public school projects. This result indicates a disruption in technical efficiency with the introduction of the policy. The coefficient for $SDFW_{93}$ *Project* is negative suggesting that the projects covered by the second stage of the SDFW (from 20 August 1993 to the end of our data in 1995) were characterized by lower inefficiency. The difference between these projects and those that are not covered by this stage of the SDFW is statistically significant at the 0.03 level, for a one-tailed test, and at the 0.06 level, for a two-tailed test. Additionally, this coefficient is relatively large indicating a 31.8 percentage point efficiency advantage for projects covered by the second stage of the SDFW. Considered together, the results for *$SDFW_{92}$ Project* and *$SDFW_{93}$ Project* suggest that the introduction of the SDFW in March of 1992 was associated with a decrease in construction efficiency. However, by the time of the expansion of the policy 17 months later, the construction industry had adjusted to wage requirements by increasing efficiency.

Table 2: Stochastic frontier (maximum likelihood) estimate of school construction output

Stochastic Frontier **Y = Ln Square Feet** **Variable**	**Coefficient**	**Inefficiency Estimates** **Y = (U)** **Variable**	**Coefficient**
Constant	-1.611***	Constant	0.056
	(0.231)		(0.044)
Ln Bid	0.805***	$SDFW_{92}$	0.086$^{\tau}$
Price	(0.016)	Project	(0.055)
Ln Stories	0.191***	$SDFW_{93}$	-0.318$^{\tau\tau}$*
	(0.061)	Project	(0.165)
Vancouver	0.098***		
	(0.032)		
Wet Season	-0.012		
	(0.034)		
Addition	-0.246***		
	(0.034)		
Year	-0.032***		
	(0.010)		
Log Likelihood =	-84.444		
LR Test (one-sided error)=	57.368		
Variance Parameters:			
Sigma-squared (u)=	0.097		
Gamma=	0.010		
Mean Efficiency=	0.946		
N =	438		

Source: Canadata, 1989 to 1995. Standard errors in parentheses. *** significant at the 0.01 level (two-tailed test). ** significant at the 0.05 level (two-tailed test). * significant at the 0.10 level (two-tailed test). $^{\tau\tau\tau}$ SDFWt coefficient is significant at the 0.01 level (one-tailed test). $^{\tau\tau}$ SDFWt coefficient is significant at the 0.05 level (one-tailed test). $^{\tau}$ SDFWt coefficient is significant at the 0.10 level (one-tailed test)

We briefly discuss the results of the maximum likelihood estimate of school construction output (Stochastic Frontier Model) that are reported under columns 1 and 2 in Table 2. The coefficient for *Ln Real Bid Price* is statistically significant, but less than one indicating decreasing returns to scale in school construction. The coefficient for *Ln Stories* confirms the efficiency of multi-storied buildings that add to size, without requiring additional foundation work, holding expenditures constant. Schools built in Vancouver are approximately 10% larger, holding project expenditure constant. This statistically significant difference for projects located in the capital city may be due to greater access to input markets and more developed infrastructure. The sign of the coefficient for Wet Season suggests that projects started during high precipitation months (December through March) are smaller for a given expenditure. However, this effect is not statistically significant. Additions, which involve work around existing structures, are associated with fewer square feet, holding expenditures constant. This difference is statistically significant at the 0.01 level. The sign of the coefficient for Year suggests that projects decrease in size by approximately 3% with the passage of each year. The difference is statistically different at the 0.01 level. This finding may be an artefact of the recession in the construction industry during the early 1990s. As the industry recovered, as input prices increased, project sizes would diminish for a given expenditure.

A likelihood ratio test of the one-sided residuals indicates that the maximum likelihood model is a significant improvement (at the 0.05 level) over an OLS estimate (the critical value is 8.761). Variance parameters reported in Table 3 indicate that sigma-squared (σ^2), the sum of the variances of the two error terms (or, $\sigma^2 = \sigma^2_v + \sigma^2_u$), equals 0.097. Gamma is the proportion of the total variance in the model that is attributed to the inefficiency effects (or, (= [$\sigma^2_u /(\sigma^2)$]). This parameter indicates that 1.0% of the total variance is explained by the inefficiency effects. This implies that the random effects (v) are more important in explaining the total variance of the model than are the inefficiency effects (u). This suggests substantial variation in the production frontier across school construction projects, but relatively little variation of observed output beneath the frontier. The average level of technical efficiency for all school projects included in the sample is 94.6%.

CONCLUSION

Our examination of the impact of prevailing wage legislation on construction inefficiency reveals that the introduction of the fair wage policy in British Columbia was associated with a statistically significant decrease in the technical efficiency of covered public school projects. However, by the time of the expansion of the policy 17 months later, the technical efficiency of covered projects was substantially higher than other public school projects. The short-lived efficiency decrease, followed by a sharp increase in productivity, may explain our previous finding of an absence in the change in the relative size of private and public school projects with the introduction of the SDFW (see Duncan *et al*. 2006). During the period of reduced efficiency associated with the introduction of the policy, competitive pressures may have prevented contractors from altering project size (for a given expenditure) until adjustments were made. These adjustments may have been relatively easy given that labour costs for primary contractors in 1998 were approximately 18% of total costs, 38% of total cost if subcontract work is deleted (see CANSIM). With the subsequent increase in productivity, there were no longer any pressures to adjust the relative size of public projects. This pattern may also explain why others have failed to find a statistically significant impact of the SDFW on the cost of British Columbian school construction projects (see Bilginsoy and Philips 2000).

REFERENCES

Aigner, D, Lovell, K and Schmidt, P (1977) Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, **6**, 21–37.

Bilginsoy, C and Philips, P (2000) Prevailing Wage Regulations and School Construction Costs: Evidence from British Columbia. *Journal of Education Finance*, **24**, 415–32.

CANSIM, Table 034-0001, *Statistics Canada*, 1998–2000.

Coelli, T (1996) A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation. *CEPA Working Paper 96/07*. Centre for Efficiency and Productivity Analysis, University of New England, Armidale, NSW 2351, Australia.

Duncan, K, Philips, P and Prus. M (2006) Prevailing Wage Legislation and Public School Construction Efficiency: A Stochastic Frontier Approach. *Construction Management and Economics*, **24**, 625–34.

Duncan, K and Prus, M (2005) Prevailing Wage Laws and Construction Costs: Evidence from British Columbia's Skills Development and Fair Wage Policy. *In:* H Azari-Rad, P Philips and M Prus (eds) *The Economics of Prevailing Wage Laws*. Burlington, VT: Ashgate Publishing Co.

Dunn, S, Quigley, J and Rosenthal, L (2005) The Effects of Prevailing Wage Requirements on the Cost of Low-Income Housing. *Industrial and Labor Relations Review*, **59**, 141–57.

Globerman, S, Stanbury, W and Vertinsky, I (1993) Analysis of Fair Wage Policies: British Columbia and Other Jurisdictions. Unpublished manuscript, University of British Columbia, October.

Risager, O (1993) *Labor Substitution in Construction and the Metal Industry in Denmark*. Working Paper, Aarhus Institute of Economics, Aarhus, Denmark.

Statistics Canada (1995) *Construction Price Index*, Price Division, First Quarter, 1993 and Third Quarter.

Tan, W (1996) The Elasticity of Capital-Labor Substitution in Singapore Construction. *Construction Management and Economics*, **14**, 537–42.

Thieblot, A (1995) State Prevailing Wage Laws: An Assessment at the Start of 1995. Rosslyn, VA: Associated Builders and Contractors.

Warszawski, A (1990) *Industrialization and Robotics in Building*. London: Harper and Row.

.

PERT VERSUS MONTE CARLO SIMULATION IN LOW RISK PROJECTS

K. Kirytopoulos[1], V. Leopoulos[2] and V. Diamantas[3]

Department of Financial and Management Engineering, University of the Aegean, 31 Fostini St, 82100 Chios, Greece
Sector of Industrial Management and Operational Research, Department of Mechanical Engineering National Technical University of Athens, 9 Iroon Polytexneiou St, 15780 Zografou, Greece

Project time management has been a major issue since the construction industry began. It includes activity definition, activity sequencing, activity duration estimating and schedule development. Schedule development techniques include the critical path method (CPM), Program Evaluation and Review Technique (PERT), and simulation methods such as Monte Carlo simulation (MCS). During this research the results of PERT, for 21 construction projects, were compared with those of standard MCS. The aim was to investigate whether the differences in the results produced by the two techniques are important and whether, in low risk projects, it is worth investing time and resources to perform MCS. The findings reveal that the produced differences will probably not change a project manager's decision. The construction projects under review were undertaken by small or medium size contractors. In this context, the project team usually cannot define the right distributions to model the duration of the activities involved, owing to lack of experience, time, resources and historical information. Typically, the use of MCS instead of PERT is more efficient and provides more precise results. However, small and medium size contractors that mainly deal with small and medium size projects with low risk may continue using PERT, if MCS cannot be their choice.

Keywords: construction planning, estimating, project management, risk analysis, simulation.

INTRODUCTION

Project risk has been defined as 'an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality. A risk may have one or more causes and, if it occurs, one or more impacts' (PMI 2004). This paper focuses on the first of these four objectives, time, and provides a comparative study, in order to come up with conclusions concerning the available techniques for activity duration estimating and schedule development.

The core problem of project time management is about activity definition, activity sequencing, activity resource estimating, activity duration estimating, schedule development and schedule control. The outcome of project time management is a project schedule that includes start and finish dates of each activity. The project is unlikely to finish on schedule if either the duration of activities or the definition of dependencies is not realistic (Diamantas *et al*. 2006).

[1] kkir@central.ntua.gr
[2] vleo@central.ntua.gr
[3] vdiamant@mail.ntua.gr

The most commonly used techniques for activity duration estimating are the expert judgement, the analogous estimating and the three-point estimates. Furthermore, the most commonly used techniques for schedule development are the critical path method – CPM (Maylor 2003), the Program Evaluation and Review Technique – PERT (Malcolm *et al*. 1959) and simulation methods such as Monte Carlo simulation – MCS (van Slyke 1963).

CPM is a mathematically based algorithm for scheduling a set of project activities. It was developed in the 1950s in a joint venture between DuPont Corporation and Remington Rand Corporation for managing plant maintenance projects (Maylor 2003). Today, it is commonly used with all forms of projects, including construction, software development, research projects, engineering and plant maintenance, among others. It can be applied for the scheduling of any project with interdependent activities.

PERT is a well-known method with proven value in managing complex projects. It was developed in 1958 by the US Navy Special Projects Office as part of the Polaris mobile submarine launched ballistic missile project (Malcolm *et al*. 1959). The development of PERT was based on the assumption that the duration of any activity within a project can be adequately modelled by the beta distribution. Initially, the mean and the variance of the duration, for each activity i, were estimated as:

$$\mu_i = \frac{1}{6} \cdot \left(a_i + 4 \cdot m_i + b_i\right) \tag{1}$$

$$\sigma_i^2 = \frac{1}{36} \cdot \left(b_i - a_i\right)^2 \tag{2}$$

where a, m and b are the optimistic, most likely and pessimistic durations of activity i. Based on the central limit theorem, the distribution describing project duration is approximately normal, with the mean value of the project duration equal to the sum of the means of the critical activities. The variance of the project duration is the sum of the variances of the same critical activities.

A limitation of PERT is that since it is limited by the constraints of the central limit theorem it is obligatory to model the duration of every activity of a project with the same statistical distribution, while the statistical distributions of all the tasks are assumed to be independent. Additionally, it ignores all ‘sub-critical’ paths, taking into account a unique critical path calculated on the basis of expected activity durations (Pagnoni 1990).

Another important issue regarding PERT is the accuracy of the utilized estimators. Keefer and Verdini (1993) presented a numerical comparison of estimation methods, arguing that the use of the original PERT estimators can lead to large errors in project duration estimating, comparable in magnitude to those ones deriving from assuming a single critical path, when the longest path cannot be predetermined with certainty. They concluded that the Extended Pearson–Tukey (Pearson and Tukey 1965) estimators as well as the Extended Swanson–Megill (Megill 1977) estimators offer substantial advantages over the original PERT estimators.

Extended Pearson–Tukey:

$$\mu = 0.630x(0.50) + 0.185\left[x(0.05) + x(0.95)\right]$$
$$\sigma^2 = 0.630\left[x(0.50) - \mu\right]^2 + 0.185\left(\left[x(0.05) - \mu\right]^2 + \left[x(0.95) - \mu\right]^2\right)$$

Extended Swanson–Megill:

$$\mu = 0.400x(0.50) + 0.300\left[x(0.10) + x(0.90)\right]$$
$$\sigma^2 = 0.400\left[x(0.50) - \mu\right]^2 + 0.300\left(\left[x(0.10) - \mu\right]^2 + \left[x(0.90) - \mu\right]^2\right)$$

The *x*(0.05), *x*(0.10), *x*(0.50), *x*(0.90) and *x*(0.95) values in the Extended Pearson–Tukey and Extended Swanson–Megill formulas correspond to the durations related to 5%, 10%, 50%, 90% and 95% percentiles respectively.

According to Lau and Somarajan (1995), the original PERT estimators can be at best considered marginally defensible only after one recognizes certain implicit restrictions that are not clearly reasonable. On the other hand, Kamburowski (1997) defends the original PERT estimators.

Another approach, presented by Vose (2000), to define distributions is to ask the expert to give estimates concerning a practical minimum (a), most likely (m) and practical maximum (b) for each estimated parameter. The practical minimum and practical maximum are defined through the selection of appropriate p and q, where p is the probability that the minimum could be below a and q is the probability that the maximum could be over b.

Nevertheless, the original PERT estimators, shown in Equations 1 and 2, are still widely taught, cited and used in practice (Vose 2000; Burke 2002; Maylor 2003; Goodpasture 2004; Rad and Anantatmula 2005; Dinsmore and Cabanis-Brewin 2006).

An alternative to PERT is the MCS which seems to be able to handle more complex project scheduling problems. Van Slyke (1963) was, probably, the first to suggest the use of MCS to find the cumulative distribution function of project network completion times. He also introduced the use of non-beta duration distributions. Johnson (1997) proposed the use of the convenient, triangular distribution in order to model adequately activity duration. In MCS, the random selection process is repeated several times so as to create multiple scenarios. Each time a value is randomly selected for every variable of the objective function, a possible scenario is formed that leads to a certain outcome. This process is called iteration. The synthesis of all the iterations gives a range of possible outcomes. In its implementation, MCS can use the three-point duration estimation approach to establish a statistical distribution of the duration of each activity (Wang 2005).

It was concluded that MCS solves most of the limitations that PERT faces. Since it is not based on the central limit theorem, activity durations may be modelled by different distributions allowing the definition of the most applicable distribution for each activity instead of defining the most convenient distribution for a group of activities (Diamantas *et al.* 2006). Distributions being mainly used for the modelling of activity duration are the beta, the triangular, the uniform and the normal ones (Kirytopoulos *et al.* 2001). Likewise, no statistical independence is assumed for activity durations. MCS takes also into account potential changes in the critical path, successfully taking into consideration the effect of 'sub-critical' paths on the duration of the project. Thus, it can be concluded that a simulation tool, such as MCS, would always provide more reliable information than PERT.

However, a major methodological deduction, experienced even in MCS, is the assumption of statistical independence for individual activities which share risk factors with other activities (van Dorp and Duffey 1999), as well as the use of a single distribution, usually the beta or triangular, to model the activity duration of all the activities due to the frequent lack of sufficient data required to define a distribution with more complex parameters (Nasir *et al*. 2003). The implementation of MCS in such a context minimizes the method's advantages over PERT and creates a false assumption regarding the reliability of the results produced. In fact, in such cases, the MCS results do not differentiate significantly from the results of standard PERT.

It is argued here that this situation is frequently encountered in small and medium size contractors dealing mainly with low risk small and medium projects. An additional aspect supporting this argument is the fact that many project managers working in such contractors do not have formal project management education, relying only on past experience and tacit knowledge; skills developed through experience (Nonaka and Takeuchi 1995). Finally, in many cases there is no formal project management process in the company.

RESEARCH METHOD

A five-step method was followed in this study. The first step was the selection of the case studies that would be explored. Twenty-one construction projects undertaken by four small and medium size contractors, based in Greece, were selected. The sole common characteristic of these projects was that they were identified as low risk projects by the contractors involved.

The second step was the development of the 'project model' for every project under examination. The project model was a schedule network for each project that was created through a project scheduling software.

An activity duration estimating team (third step) was formed for each contractor, consisting of individuals (belonging to each contractor's staff) with project management experience. None of the contractors maintained a corporate knowledge repository, meaning that the project team did not have access to historical information.

The fourth step was the activity duration estimating. Since historical information was not available, the activity duration estimating team lacked sufficient data required to define the right distribution, and modelled the duration of each activity with a beta distribution, following the process of the standard PERT. Although not correct, this deduction is common practice for SMEs. The three-point estimate approach was used, requiring the estimation of an optimistic (minimum), a most likely, and a pessimistic (maximum) value for the duration of each activity. These values were estimated by the activity duration estimating team, based on its tacit knowledge acquired from similar projects. The activity duration estimation team had difficulty in answering meaningfully any question regarding a percentile of the activity duration (for example 5% and 95% or 10% and 90%) based on tacit knowledge, which was another reason for using the standard PERT estimators shown in Equations 1 and 2.

The fifth step was the conduction of PERT analysis and MCS and the comparison of the generated results. PERT was calculated through the use of the original estimators of Equations 1 and 2, while the critical path was defined based on the expected duration values. In MCS the activity duration estimating lacked the required data to define the right distribution and chose to use a beta distribution as in standard PERT. Additionally, they used the three-point estimate approach to define this Beta distribution based on the same three-point estimations (a, m, b) used in PERT.

FINDINGS AND DISCUSSION

Table 1 presents the differences (as a percentage) between the project duration for each confidence level produced by PERT and MCS for the 21 projects under investigation. These differences were calculated through the use of the formula

$$\frac{D_{MCS} - D_{PERT}}{D_{PERT}}$$

The information provided by Table 1 is that the calculated differences are quite low. However, the simulation approach provides more pessimistic results than PERT, as expected.

The confidence level is defined as the probability that a project will be completed in less or equal time than the duration corresponding to the confidence level.

The deterministic duration, calculated by CPM, and the probability that the project will be completed in less or equal duration than this value (the confidence level) in both PERT and MCS approach is given in Table 2. The results of the deterministic approach correspond to very low confidence levels, in either PERT or MCS. The maximum confidence level that the results of CPM correspond to either PERT or MCS is 35%. Planning based on such a confidence level provides a false feeling of safety and leads to decision making based on misleading information.

The mean value of the produced differences between PERT and MCS, for each confidence level and for the mean value of project duration, are presented in Table 3. The results presented in Table 3 show that the results produced from MCS, when activity duration estimating is made without the guidance of historical data, are similar and even identical in some cases with those of standard PERT. The results show that the difference of the mean values produced by MCS and PERT is approximately 0.80%, while the mean value of the difference between PERT and MCS in the 90% confidence level of project duration is approximately 1.34%. These differences might not be negligible; however, they will probably not change the decision of a project manager.

These differences, presented in Tables 1, 2 and 3 are solely generated by the effect of the sub-critical paths of each project, taken into account in MCS.

The comparison of the duration calculated by PERT and the duration simulated with the actual duration of the project is presented in Table 4. It should be noted that the duration presented as actual duration for the projects with duration greater than 270 days (refer to Table 2 – CPM duration) is the estimated project duration since these projects are still in progress and is denoted with the abbreviation ‘est’.

It is important to point out that from the 21 projects under investigation only eight of them have an actual duration, or estimated project duration, that corresponds to the confidence levels that managers usually take into account, i.e. the 70–85% range. The actual duration, or estimated project duration, of the remaining projects corresponds to a minimum confidence level of 95%, while many of them are larger than the maximum duration calculated from both PERT and MCS.

Estimated project duration is the current estimation of the project team regarding the total duration of the projects still in progress. This estimation is subject to updates due to possible changes in the conditions affecting project duration until the completion of the project.

Table 1: Produced differences (%) between PERT and MCS durations for specific percentiles, for the 21 projects under investigation

Project No. Percentile	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
5%	–0.60	1.93	–0.63	0.00	–0.22	1.37	2.22	0.04	3.38	–0.69	0.87	–0.06	0.46	–1.19	1.08	–0.45	2.86	0.38	–0.81	1.40	–0.45
10%	–0.56	1.17	–0.54	–0.07	–0.36	1.28	2.09	–0.18	3.06	–0.38	0.75	–0.02	0.10	–1.70	0.78	–0.22	2.82	0.21	–1.01	1.38	0.01
20%	–0.42	1.23	–0.36	–0.05	–0.28	1.32	2.05	–0.30	2.74	0.03	0.57	0.09	0.38	–1.57	0.59	–0.45	2.70	0.63	–0.86	1.34	–0.07
30%	–0.34	0.79	–0.29	–0.05	–0.12	1.33	1.99	–0.26	2.61	–0.09	0.79	0.21	0.40	–1.25	0.76	–0.51	2.72	0.49	–0.52	1.36	0.05
40%	–0.17	0.59	–0.14	0.05	0.00	1.33	1.96	–0.14	2.44	0.05	0.84	0.29	0.71	–0.79	0.99	–0.39	2.74	0.47	–0.35	1.42	0.15
50%	–0.09	0.14	0.01	0.13	0.12	1.39	1.95	–0.03	2.34	0.13	0.79	0.43	1.01	–0.22	1.28	–0.26	2.74	0.72	–0.16	1.43	0.12
60%	0.09	0.01	0.11	0.22	0.27	1.41	1.93	0.19	2.23	0.22	0.84	0.54	1.02	0.33	1.60	–0.03	2.73	1.05	0.17	1.44	0.36
70%	0.21	–0.22	0.23	0.33	0.43	1.44	1.90	0.41	2.25	0.25	0.88	0.59	1.46	0.77	1.91	0.20	2.72	0.98	0.29	1.53	0.27
80%	0.41	–0.59	0.37	0.43	0.57	1.48	1.89	0.71	2.20	0.48	0.99	0.71	1.55	1.17	2.36	0.56	2.76	1.21	0.60	1.68	0.66
90%	0.43	–0.53	0.52	0.57	0.82	1.58	1.82	1.14	2.10	0.42	1.27	0.91	1.98	1.75	2.70	1.29	2.83	1.82	1.03	1.86	1.78
95%	0.64	–1.19	0.62	0.66	1.01	1.65	1.67	1.27	2.14	0.49	1.67	1.18	2.18	2.05	2.65	1.51	2.88	1.58	1.31	2.02	1.97

Table 3: CPM durations for each one of the 21 projects and their corresponding confidence levels in PERT and MCS

Project no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CPM duration (days)	188	21	453	1496	82	1364	247	168	217	308	107	260	235	78	1034	120	320	121	305	94	221
Conf. level – PERT	30%	30%	35%	30%	25%	25%	32.5%	20%	12.5%	25	15%	30%	27.5%	35%	35%	20%	25%	20%	32.5%	<5%	22.5%
Conf. level – MCS	35%	30%	30%	32.5%	25%	15%	17.5%	20%	<5%	25%	10%	27.5%	20%	37.5%	32.5%	20%	<5%	15%	35%	<5%	22.5%

Table 5: Mean value (%) of produced differences between PERT and MCS

Percentile	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	Mean
Mean	0.52%	0.41%	0.42%	0.44%	0.46%	0.48%	0.53%	0.57%	0.63%	0.67%	0.72%	0.80%	0.84%	0.90%	0.97%	1.06%	1.18%	1.34%	1.43%	0.80%

Table 7: Actual project durations for each one of the 21 projects and their corresponding confidence levels in PERT and MCS

Project no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Actual duration	206	24	487est	1700 est	88	1530 est	265	180	252	328	114	320	263	86	1350 est	129	348 est	140	330 est	105	241
Conf. level – PERT (%)	99	92	99	>100	84	99	89	66	100	94	81	>100	96	89	>100	70	100	100	81	92	95
Conf. level – MCS (%)	98	95	98	>100	80	>100	78	64	98	90	75	>100	88	75	>100	68	93	99	78	80	90

CONCLUSIONS

The objective of this study was to present one major methodological deduction in MCS, which is frequently met in practice. This methodological deduction consists of both the modelling of the duration of activities with the same distribution, usually the beta or triangular one and the lack of historical information within the activity duration estimating phase. The authors argued that under particular circumstances the project duration estimating process will not provide significantly different results when MCS is applied instead of standard PERT. Twenty-one case studies were explored validating the initial hypothesis.

Such particular circumstances may occur when the lack of historical information does not allow the duration estimating team to define the right distribution in order to model the duration of each activity. Furthermore, the duration estimating team, based solely on tacit knowledge, is unable to meaningfully define different distributions in order to model the duration of each activity. Thus, a single distribution is used for the modelling of the duration of all project activities.

These circumstances were met in all four small and medium size contractors under investigation and are frequently met in small and medium size contractors.

In such a context the application of MCS instead of PERT during the project duration estimating process may not provide the anticipated results. Specifically, the results produced by the MCS technique under these circumstances are similar to, or even the same as, the results produced by standard PERT, providing a misleading assumption regarding the reliability of the results, and the efficiency of modelling reality. Therefore, it is concluded that small and medium size contractors, which mainly deal with small and medium size projects with low risk, may continue using PERT, if MCS cannot be their choice.

On the other hand, the results of the deterministic approach (CPM) correspond to very low confidence levels, in either PERT or MCS, indicating that the use of a stochastic approach is necessary.

However, it should be noted that the application of simulation techniques instead of deterministic or non-simulation stochastic approaches, such as CPM and PERT, during the duration estimating process, allow the more efficient modelling of the project and provide more precise and reliable results. Thus, in general, simulation techniques are greatly preferred to deterministic or non-simulation stochastic approaches. The simulation approach provides more conservative results, however closer to reality, as it takes into account several parameters that can differentiate the completion date of a project. Such parameters include the use of the right distributions (i.e. strongly positively skewed, distributions that overemphasize the tail), the better modelling of all kinds of risks and the consideration of sub-critical paths.

It is perhaps less obvious but just as important to note that during this research it was assumed that uncertainty can be adequately modelled with the three-point duration estimation.

The authors have already focused their future research on the effect of the additional parameters, which simulation approaches can take into account, on project duration estimating. Two critical issues have been recognized so far. The first issue is the effect of the definition of the right distribution for the modelling of the duration of each activity on project duration estimating. The second issue regards risk handling and whether the three-point duration estimation approach can adequately model uncertainty or not.

REFERENCES

Burke, R (2002) *Project management, planning & control techniques.* New York: John Wiley & Sons.

Diamantas, V, Kirytopoulos, K and Leopoulos, V (2006) Simulation in project scheduling: why PERT is not enough. *In*: U Baake and E Yukesan (Eds.) *3rd Future Business Technology Conference*, 17–19 April 2006, Athens. The European Simulation Society, 64–70.

Dinsmore, P and Cabanis-Brewin, J (Eds.) (2006) *The AMA handbook of project management*. 2ed. AMACOM.

Goodpasture, J (2004) *Quantitative methods in project management*. Boca Raton, FL: J. Ross Publishing.

Johnson, D (1997) The triangular distribution as a proxy for the beta distribution in risk analysis. *Statistician*, **46**(3), 387–98.

Kamburowski, J (1997) New validations of PERT times. *Omega*, **25**(3), 323–8.

Keefer, D L and Verdini, W A (1993) Better estimation of PERT activity time parameters. *Management Science*, **39**, 1086–91.

Kirytopoulos, K, Leopoulos, V and Malandrakis, C (2001) Risk management: a powerful tool for improving efficiency of project oriented SMEs. *In:* H Hvolby (Ed.) *4th International Conference on Small and Medium Sized Enterprises: Management – Marketing – Economic Aspects*, 14–16 May 2001, Aalborg University. Department of Production Aalborg University, 331–9.

Lau, H-S and Somarajan, C (1995) A proposal on improved procedures for estimating task-time distributions in PERT. *European Journal of Operational Research*, **85**, 39–52.

Malcolm, D G, Rooseboom, J H, Clark, C E and Fazer, W (1959) Application of a technique for research and development program evaluation. *Operations Research*, **7**, 646–69.

Maylor, H (2003) *Project management*. 3ed. Harlow: Pearson Education.

Megill, R E (1977) *An introduction to risk analysis*. Tulsa: Petroleum Publishing Company.

Nasir, D, McGabe, B and Hartono, L (2003) Evaluating risk in construction – schedule model (ERIC-S): construction schedule risk model. *Journal of Construction Engineering and Management*, **129**(5), 518–27.

Nonaka, I and Takeuchi, H (1995) *The knowledge-creating company*. Oxford: Oxford University Press.

Pagnoni, A. (1990) *Project engineering: computer-oriented planning and operational decision making.* Berlin: Springer-Verlag.

Pearson, E S and Tukey, J W (1965) Approximate means and standard deviations based on distances between percentage points of frequency curves. *Biometrika*, **52**, 533–46.

PMI (2004) *A guide to the project management body of knowledge* (PMBOK). Newtown Square, USA: Project Management Institute.

Rad, P and Anantatmula, V (2005) *Project planning techniques*. Vienna: Management Concepts.

Van Dorp, J R and Duffey, M R (1999) Statistical dependence in risk analysis for project networks using Monte Carlo methods. *International Journal of Production Economics*, **58**, 17–29.

Van Slyke, R M (1963) Monte Carlo methods and the PERT problem. *Operations Research*, **11**(5), 839–60.

Vose, D (2000) *Risk analysis: a quantitative guide*. 3ed. Chichester: John Wiley & Sons.

Wang, W C (2005) Impact of soft logic on the probabilistic duration of construction projects. *International Journal of Project Management*, **23**(8), 600–10.

CONSTRUCTION SPEED INDICATORS AND THEIR ESTIMATION

Christian Stoy[1]

[1]*Institute for Construction Economics, University of Stuttgart, Keplerstr. 11, 70174 Stuttgart, Germany*

The use of a series of independent variables for an early estimation of the construction speed [m^2 gross external floor area/month] of Swiss building construction projects is proposed. Based on 200 properties, these variables serve as the speed drivers of a project, and the regression model, tested against the 200 properties, has a mean absolute percentage error of 16%. When applied to predict the speed of 25 more properties that were excluded from the 200 in the regression model, the percentage error ranges between –39% and 25%. The identified speed drivers are: project size, number of winters and type of use.

Keywords: construction duration, construction speed, regression model, Switzerland.

INTRODUCTION

Construction duration is a critical success factor of each construction project. Therefore the speed with which building proceeds (construction speed) plays an important role in the commercial success of a construction project. A construction duration that is too long, as well as one that is too short, can have a negative impact on the project's success. For this reason, planning the construction duration and/or speed must be included along with cost and quality planning as one of the major tasks of construction project management.

Only a few resources to support planning the construction speed, similar to those used for cost planning for example, have previously been available in Switzerland. The lack of indicators and models supporting an early estimate of the construction speed is particularly serious. The present study deals with this deficit. Using the analysed data as a basis, the relevant drivers, as well as indicators based on them, are clearly articulated and a regression model for estimating the construction speed is derived.

These analyses are based on primary data from 225 properties. On this basis, indicators and their drivers can be designated. Thus the remarks of this paper are based on concrete construction projects whose data are available on a uniform basis. In addition to the data pool, however, this study also builds on studies which hitherto have not delivered a uniform and thus a conclusive picture of important drivers. Prominent emphasis must be given to the work by Bromilow *et al*. (1980), which considers the connection between construction duration and building construction costs. In addition, however, the advanced studies by Chan and Kumaraswamy (2002) and Love *et al.* (2005) must be mentioned, which primarily examine project-specific characteristics, such as project size and type of façade construction, and their

[1] info@bauoekonomie.uni-stuttgart.de

influence on construction duration. But what is still lacking in spite of this work, above all for Switzerland, are indicators and models that build on a wide data pool.

The described study proposes an initial approach for attaining the objective set forth above. In the first section of this paper, the author presents the results of his study of the secondary literature. He primarily addresses the question of the different relevant drivers influencing construction speed. The second section is devoted to the data pool, which is introduced briefly. Additionally the characteristics of the proposed model and their drivers are presented in detail. In the concluding section the results of the data analysis are summarized.

LITERATURE REVIEW

Construction speed

A construction project passes through several phases. It begins with a concept and continues though the preliminary studies, planning, the construction process, and on to the new facility's start of operations. This study deals exclusively with the project's construction process, which is defined as the construction duration from the start of work at the construction site until the entire work is completed.

The construction speed defines the average progress of construction over the construction duration. Normal units of measure are revenue [€ revenue/month], area completed [m^2 gross external floor area/month], or volume completed [m^3 building volume/month]. This study defines construction speed using floor area, i.e. the study's functional unit parameter [m^2 gross external floor area/month].

State of the art

There are already studies available that evaluate drivers of construction duration and, in part, of the construction speed of new construction projects. Table 1 summarizes these studies. For reasons of scope, no consideration has been given here to studies that are concerned, for example, with civil engineering projects or the reasons for construction delays (for example Al-Khalil and Al-Ghafly 1999).

Based on the secondary literature, it is possible to identify relevant drivers. There are 11 studies in this connection, which are presented briefly below.

Table 1: Related studies and their relevant drivers

Study	**Data pool (country)**	**Relevant drivers**
Bromilow *et al*. (1980)	395 (Australia)	Building construction costs Building age Client (government/private)
Chan and Kumaraswamy (1995)	111 (Hong Kong)	Client (government/private) Project type (building/civil engineering works) Building construction costs Gross floor area Number of levels
Walker (1995)	33 (Australia)	Building construction costs Work type (fit-out, etc.) Client objectives Management style Communication (between architect/engineer and contractor) Use of information technology

Study	Data pool (country)	Relevant drivers
Chan (1999)	110 (Hong Kong)	Building construction costs Client (government/private)
Chan and Kumaraswamy (1999)	56 (Hong Kong)	External wall area Number of levels above ground Average floor size Frame type (presence/absence of precast façades) Type of foundation Communication (between architect/engineer and contractor) Type of scheme (rental/purchase)
Boussabaine (2001)	230	Building construction costs Type of call for tenders Tender type Contract type
Chan (2001)	51 (Malaysia)	Building construction costs
Chan and Kumaraswamy (2002)	71 (Hong Kong)	Building construction costs Frame type (presence/absence of precast façades) Building volume Average floor size Type of scheme (rental/purchase)
Ng *et al*. (2001); Skitmore and Ng (2003)	93 (Australia)	Building construction costs Type of use (education/residential, etc.) Type of call for tenders Tender type Client (government/private) Building age
Love *et al*. (2005)	161 (Australia)	Gross floor area Number of levels

EMPIRICAL STUDY

Available data

The data pool is formed by 225 Swiss construction projects. These are properties from different construction companies, for which not all of the relevant drivers can be recorded owing to limits on the data provided (cf. Table 1). Especially so-called ‘soft’ drivers, such as client objectives, management style, communication (between architect/engineer and contractor), and use of information technology are not available. The detailed description of the data pool can be found in the Annex to this paper (cf. Table 5, Table 6 and Table 7).

The data pool encompasses 225 real properties that are assigned the following types of use:

- office (R = 55);
- residential (R = 83);
- other types of use, e.g. cultural, sport, education, health (R = 87).

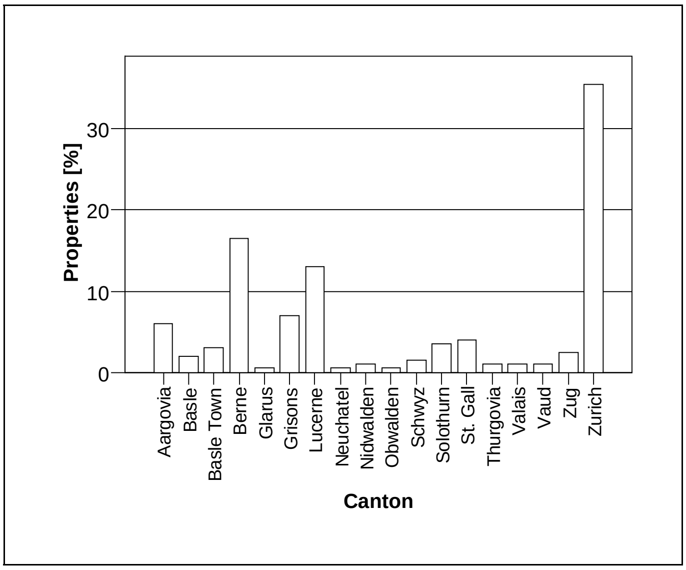


Figure 1: Geographic distribution of properties (%) (R = 225)

The geographic distribution of the survey sample is shown in Figure 1. It becomes apparent that the large Canton of Zurich is prominently represented. The absolute size of the properties can be specified in m^2 of gross external floor area, with the sample showing a median size of 7545 m^2 (mean of 11 408 m^2, lower and upper quartiles respectively of 2276 m^2 and 14 723 m^2).

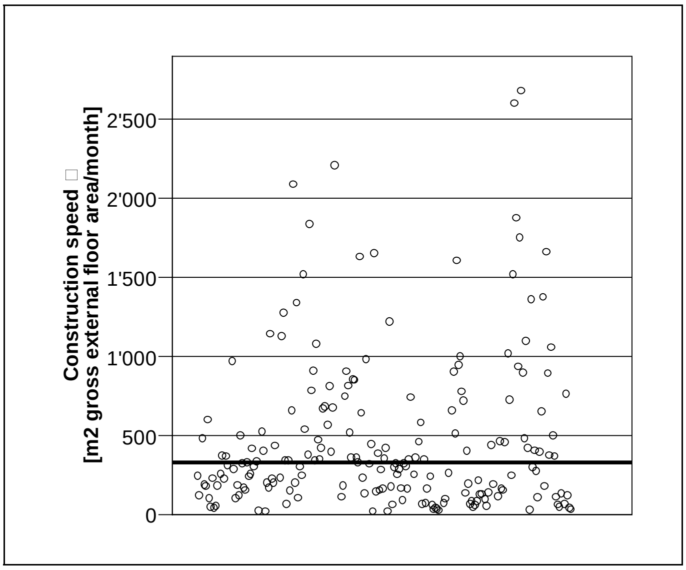


Figure 2: Construction speed indicators (R = 225) (median is shown)

On the basis of the sample survey, the construction speed indicators are illustrated in Figure 2 (median value of 325 m^2 gross external floor area/month, mean of 493 m^2 gross external floor area/month) (R = 225). On the basis of this figure it becomes apparent that substantial differences can be found among the duration speeds of the individual properties. Thus the question arises of which are the relevant drivers that cause these differences. To answer this question, the drivers listed in Table 1 are confronted with the database.

Proposed regression model

There are several options that may be used in creating a regression model (cf. Cropper and McConnell 1988). Log-log, semi-log and linear models were examined. In past studies, log-log and linear models have produced the best results (Table 1). However, there is debate as to whether the best results are obtained using absolute construction duration [months] or construction speed [m^2 gross external floor area/month] as the dependent variable. The former produces better fits, but the latter tends to have more normally distributed errors. Each of the different methods was tested, and in this analysis the model that produced the best statistical results in terms of parameter significance was a log-log regression of m^2 of gross external floor area per month (Table 2).

Table 2: Summaries of models (dependent variable: construction speed [m^2 gross external floor area/month], R = 200)

Model	Transformation	R^2	R^2 adjusted	F-Value	Significance	MAPE [%]
1	linear (non)	0.825	0.821	229.599	0.000	83.1
2	log-log	0.966	0.966	1395.246	0.000	15.8

The 25 test properties show differences between observed and predicted construction speeds between –39% and 25% (Table 3). Additionally the proposed model shows:

- R^2 of 0.966 (R^2 adjusted of 0.966);
- mean absolute percentage error (MAPE) of 16% (Love *et al*. (2005): MAPE of 50%);
- root mean squared error (RMSE) of 123 (Love *et al*. (2005): RMSE of 221);
- mean absolute deviation (MAD) of 70.5.

Thus the quality of the developed log-log regression model can be classified as comparatively good.

Table 3: Observed and predicted construction speed of 25 test properties for Model 1 (dependent variable: construction speed [m^2 gross external floor area/month])

No. of property	Observed construction speed [m^2 gross external floor area/month]	Predicted construction speed [m^2 gross external floor area/month]	Difference [%]
3	473	439	8
20	1306	1186	10
21	353	374	–6
36	436	348	25
39	162	221	–26
49	69	104	–33
50	1531	1574	–3
67	632	570	11
79	612	580	5
85	1463	1403	4
86	607	789	–23
87	1645	1521	8
104	285	324	–12
131	128	170	–25
134	378	484	–22
141	171	233	–27
148	42	45	–6
149	34	57	–39
152	373	388	–4
154	556	495	12

No. of property	Observed construction speed [m^2 gross external floor area/month]	Predicted construction speed [m^2 gross external floor area/month]	Difference [%]
174	82	97	–15
178	313	350	–11
182	3249	2739	19
188	144	142	1
222	89	105	–15

The regression model as developed (Model 1 from Table 2) can ultimately incorporate three independent variables (Table 4):

- project size (1000 m^2 gross external floor area);
- number of winters;
- type of use (office, residential, other) (dummy).

Table 4: Coefficients table for Model 1 (dependent variable: construction speed [m^2 gross external floor area/month], R = 200)

	B	Std. error	T-Value	Significance
Project size [1000 m^2 gross external floor area]	0.881	0.013	69.325	0.000
Number of winters	–0.361	0.017	–21.411	0.000
Type of use – office	–0.054	0.038	–1.427	0.155
Type of use – other	–0.160	0.034	–4.780	0.000
(constant)	4.923	0.034	145.171	0.000

Thus the proposed model can be represented with the following equation:

$$\ln(y) = 4.923 + 0.881 \ln(x_1) – 0.361\, x_2 – 0.054 \ln(x_3) – 0.160 \ln(x_4)$$

where:

y = construction speed (m^2 gross external floor area/month)

x_1 = project size

x_2 = number of winters

x_3 = type of use – office

x_4 = type of use – other

Residential was chosen as defaults for type of use.

The back-transformed regression equation reads:

$$y = e\^(4.923) * e\^(0.881 \ln(x_1)) * e\^(–0.361x_2) * e\^(–0.054 \ln(x_3) * e\^(–0.160 \ln(x_4))$$

The explanatory contents of the drivers/independent variables that have been included vary. Using a univariate variance analysis, a rank order can be identified, which is shown in the variable sequence in the proposed equation. The greatest explanatory content can be identified for the variable ‘project size’ and the smallest content for ‘type of use’.

Causal relationships in the regression model

The causal relationships of each independent variable of the proposed model are described in the following section. It begins with the project size (measured in 1000 m^2 gross external floor area), whose impact on construction speed is represented in Figure 3. This driver/independent variable contributes the largest explanatory content, which can be quantified on the basis of the regression equation:

- If x_1 (project size measured in 1000 m^2 gross external floor area) increases by 1%, then construction speed rises by approximately 0.88%.

An average property of the available sample has approximately 11 400 m^2 of gross external floor area and a construction speed of approximately 493 m^2 gross external floor area/month. If the absolute size of this average property increases by 3000 m^2 gross external floor area (26%), the construction speed rises by approximately 23%. The construction speed indicator of an equivalent 14 400 m^2 gross external floor area property amounts therefore to 606 m^2 gross external floor area/month.

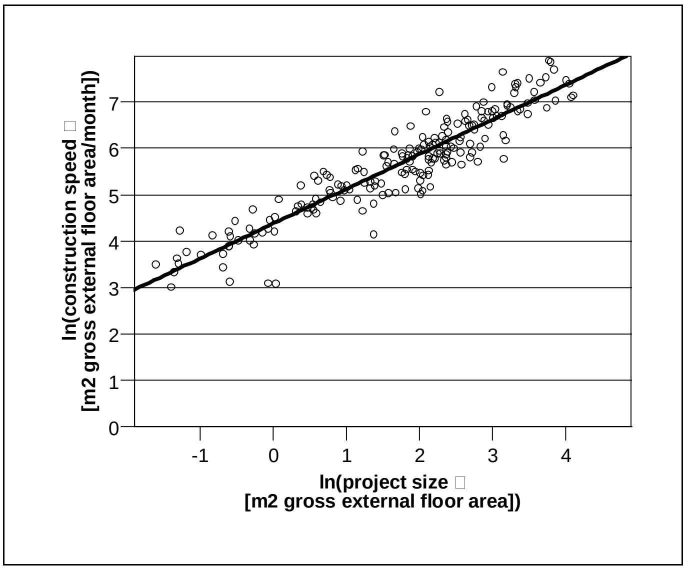


Figure 3: ln(construction speed [m^2 gross external floor area/month]) and ln(project size [1,000 m^2 gross external floor area]) (R = 200)

In contrast to the project size, the number of winters exhibits a negative speed impact (Figure 4). This means that construction speed (m^2 gross external floor area/month) decreases with an increasing number of winters during the construction process:

- According to the back-transformed regression equation it can be stated that an additional winter decreases the construction speed by approximately 30% (y = e^(–0.361 * 1)y = 0.697y).

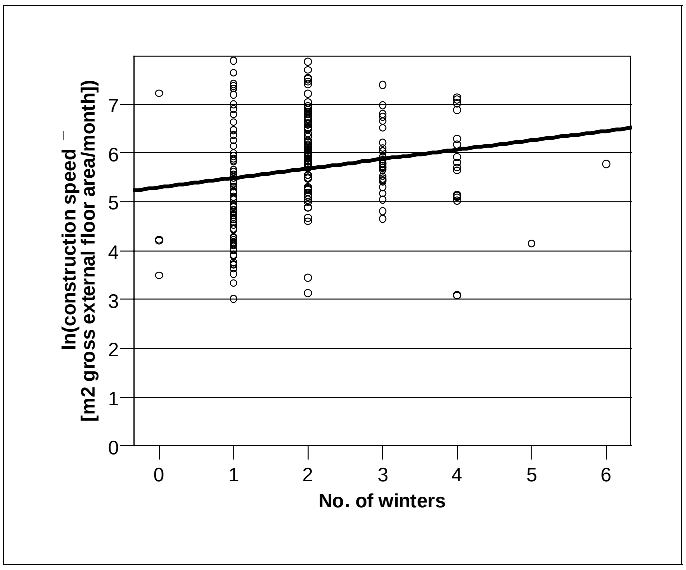


Figure 4: Construction speed and number of winters (R = 200)

The above-mentioned speed drivers are metrically scaled. In contrast, the driver ‘type of use’ (differentiated between office, residential and other) is ordinal-scaled. Therefore two dummy variables (x_3, x_4) are incorporated in the proposed model to include this speed driver. ‘Residential’ is chosen as default attribute. The following causal relationships of this driver can be quantified according to the back-transformed equation:

- ‘Office’ projects (x_3) are slower than ‘residential’ projects (approx. 5% according to the coefficient of –0.054).
- ‘Other’ projects (x_4) are slower than ‘residential’ projects (approx. 15% according to the coefficient of –0.160).

This study predominantly confirms preceding studies with the three described speed drivers. For example Love *et al.* (2005) also recognized the high influence of the project size, which is measured in m^2 gross external floor area, and they also presented a log-log regression model. On the other hand the present study supplies another driver which has received no attention so far: number of winters. This driver is shown to be relevant even if their relevance remains far less than that of project size (cf. Love *et al.* 2005).

CONCLUSION

With this study the relevant construction speed drivers are identified on the basis of 200 Swiss properties, and their causal relationships are presented in a log-log regression model. This proposed model shows a mean absolute percentage error (MAPE) of 16% and integrates the following independent variables (speed drivers):

- project size (1000 m^2 gross external floor area);
- number of winters;
- type of use (office, residential, other) (dummy).

In addition the model shows its comparatively good prognostic accuracy with the test of 25 properties which were not included in the development of the proposed model. The percentage error for these test properties lies between –39% and 25%.

Owing to limits of the available data, a set of further construction speed drivers could not be examined. Essentially these are the so-called ‘soft’ factors which Walker (1995) examined, for example:

- client objectives;
- management style;
- communication between architect/engineer and contractor;
- use of information technology.

ACKNOWLEDGMENT

The author acknowledges his professional collaborators for their contribution during the full term of the study: Allianz Suisse Real Estate, Allreal AG, city of Zurich, Credit Suisse Real Estate Investment Management, F. Hoffmann – La Roche AG, Helbling Ingenieurunternehmung AG, Karl Steiner AG, SwissRe, UBS Fund Management.

REFERENCES

Al-Khalil, M I and Al-Ghafly, M A (1999) Delay in public utility projects in Saudi Arabia. *International Journal of Project Management*, **17**(2), 101–6.

Boussabaine, A H (2001) Neurofuzzy modelling of construction projects' duration II: application. *Engineering, Construction and Architectural Management*, **8**(2), 114–29.

Bromilow, F J (1974) Measurement and scheduling of construction time and cost performance in the building industry. *The Chartered Builder*, **10**(9), 57–65.

Bromilow, F J, Hinds, M F and Moody, N F (1980) AIQS survey of building contract time performance. *The Building Economist*, **19**(September), 79–82.

Chan, A P C (1999) Modelling building durations in Hong Kong. *Construction Management and Economics*, **17**(2), 189–96.

Chan, A P C (2001) Time–cost relationship of public sector projects in Malaysia. *International Journal of Project Management*, **19**(4), 223–9.

Chan, D W M and Kumaraswamy, M M (1995) A study of the factors affecting construction durations in Hong Kong. *Construction Management and Economics*, **13**(4), 319–33.

Chan, D W M and Kumaraswamy, M M (1999) Modelling and predicting construction durations in Hong Kong. *Construction Management and Economics*, **17**(3), 351–62.

Chan, D W M and Kumaraswamy, M M (2002) Compressing construction durations: lessons learned from Hong Kong building projects. *International Journal of Project Management*, **20**(1), 23–35.

Cropper, M, Deck, L and McConnell, K (1988) On the choice of functional form for hedonic price functions. *Review of Economics and Statistics*, **70**(4), 688–75.

Love, P E D, Raymond, Y C T and Edwards, D J (2005) Time–cost relationships in Australian building construction projects. *Construction Engineering and Management*, **131**(2), 187–94.

Ng, S T, Mak, M M Y, Skitmore, R M, Lam, K C and Varnam, M (2001) The predictive ability of Bromilow's time-cost model. *Construction Management and Economics*, **19**(2), 165–73.

Skitmore, R M, and Ng, S T (2003) Forecast models for actual construction time and cost. *Building and Environment*, **38**(8), 1075–83.

Walker, D H T (1995) An investigation into construction time performance. *Construction Management and Economics*, **13**(2), 263–74.

ANNEX

Table 5: Construction speed indicator (m^2 gross external floor area/month)

	Lower quartile	**Median**	**Upper quartile**	**R**
New build properties	150	325	648	225
Office	225	461	1080	55
Residential	114	397	778	83
Other types of use	148	241	353	87

Table 6: Independent variables (metrically scaled)

	Lower quartile	**Median**	**Upper quartile**	**R**
Average floor height (m)	3.21	3.56	4.06	225
Average level size (1000 m^2 gross external floor area/level)	0.706	1.463	2.924	225
Building age in 2005 (year)	5	7	13	225
Building height (m)	12.82	17.43	24.15	225
Building volume (1000 m^3)	9.140	30.362	53.903	225
Construction cost indicator (€/m^2 gross external floor area)	1708	2519	3415	225
Construction costs (1 Mio. €)	6.143	17.874	33.391	225
Excavation volume (m^3)	4395	10048	20199	225
External wall area (m^2)	1050	2494	4606	225
Roof area (m^2)	728	1711	2931	225
Foundation area (m^2)	580	1843	3037	225
Gross external floor area (1000 m^2)	2.276	7.545	14.723	225
Building construction index change in relation to the previous year	-0.31	0.20	1.82	225
Internal wall area (m^2)	675	3182	6666	92
Number of levels	3	5	6	225
Number of levels above ground	1	1	1	225
Number of levels below ground	3	4	5	225
Number of winters	1	2	2	225
Planning duration (months)	28	37	54	225
Proportion of air-treated area of gross external floor area (%)	5	15	70	225
Number of lifts	1	2	4	225
Proportion of windows and doors of external wall areas (%)	25	35	50	225

Table 7: Independent variables (not metrically scaled)

	Spread	**R**
Site access	68% free access 28% crowded access 4% space between buildings	225
Frame type	61% skeleton construction 39% crosswalk construction	221
Topography	69% flat site 24% sloping site 6% hillside situation	225

ANALYSIS ON COMPREHENSIVE ASSURANCE OF CONSTRUCTION SCHEDULE FOR HYDROPOWER PROJECT

Liu Quan,[1] Hu Zhigen, Wang Jing and Fan Xi-e

State Key Laboratory of Water Resource and Hydropower Engineering Science, Wuhan University, Wuhan, HuBei, China

Generally, hydropower projects come with huge investment, complex construction conditions and many uncertain construction factors; hence, the research on construction risk or construction assurance is indispensable. The risk of construction schedule is the completion date of partial or whole project passes beyond the specified date. Commonly, the risk for dam constructing schedule means the risk of dam construction reaching specified levels before specified deadlines. Since the risk neglects the duration uncertainty of the working procedure and whole project, the results of risk of dam constructing schedule is lower or more optimistic than that what brings dangers to decisions and projects. Based on the analysis of the flaw in the risk of the dam construction schedule, taking into account the uncertainties in hydrological, hydraulic, and construction schedules factors, the concept of comprehensive assurance of construction schedules on dams for hydropower projects is prompted, and its calculation model is built up. By means of Monte-Carlo method and computer simulation technology, those uncertainties are synthesized into the comprehensive assurance. An instance shows that the comprehensive assurance of dam construction is a more comprehensive index to describe the risk factors of the hydropower project construction.

Keywords: risk analysis, construction planning, process modelling, Monte Carlo simulation.

INTRODUCTION

Generally, hydropower projects come with huge investment, complex construction conditions and many uncertain construction factors; hence, the research on the construction risk or the construction assurance is indispensable. In recent years, Chinese and foreign scholars have made many research achievements. The method is extended from PERT simulation to Monte-Carlo simulation (Lee 2005) or other methods (Guo 2001), and the construction duration evaluation method is extended from simple CPM to kinds of simulation method (Lu 2000). Bonnal (2004) introduces fuzzy project scheduling into the analysis of working procedure duration. In view of the uncertainty of working procedure duration, Hu (1999), Xu (1998) and Wang (1999) assume that it submits to a specified random distribution, based on the construction and experience, gains the estimation of total construction progress and the statistical distribution characteristic through network planning progress Monte-Carlo simulation and, consequently, gains the risk distribution of total construction progress. The flood impact of the flood season should also be taken into account during the construction progress of the dam. We cannot ensure which type of

[1] hapland@163.com

distribution the working procedure duration submits to. Aiming at the uncertain factors of floor peak flow, Wang (2002) researches the probability characteristic of the water level before the cofferdam, and computes the progress assurance rate of the cofferdam filling elevation by month. The progress assurance rate is calculated on the base of the cofferdam filling elevation by month, while the uncertainty of working procedure duration in the construction progress ensures that the completion time of the cofferdam filling elevation is uncertain too. It shows that above progress assurance rate is computed without considering the impact of the uncertainty of construction duration. Hence, the network progress risks and dam filling progress risks are combined to make a further analysis of dam construction progress risks, and promote the index of dam construction progress comprehensive assurance rate.

ANALYSIS OF CONSTRUCTION SCHEDULE RISK

The risk of construction schedule (Hu 1999) is the probability that the calculated partial or whole project completion date T_c of the project network programming passes beyond the specified date T_p. The mathematic expression of construction schedule risk P_r is:

$$P_r = P(T_C > T_p) \tag{1}$$

Assume that working durations are subject to a specified parameter of specified random distribution of certain types, and the computer will produce a random number as working duration according to the type of random distribution and distribution parameters on simulating, then some parameters such as the project duration, the start time and end time of each working procedure by the construction network time parameter calculation. Construction period, the probability distribution and average of every key period can be gained by simulation. The simulation flowchart of construction schedule risks by Monte-Carlo method is shown in Figure 1.

ASSURANCE ANALYSES ON DAM SHEDULE

As a specified of hydropower engineering, the dam is a time-consuming project that experiences years generally and flood flux changefully, a random process due to the uncertainty time and the flood peak flow in riverbank. At the meantime, there is uncertainty in the discharge ability of diversion structures. Consequently, it is important to figure out a reasonable plan for dam project process, which the dam should be built higher than upstream water level to ensure the dam construction, especially in the process of midterm diversion with dam retaining water.

The assurance analysis on dam schedule can be defined as the probability of the actual water level being lower than the dam elevation at that time (Hu 2002). This is presented as:

$$R_Q = P(Z_u(t) < H_u \tag{2}$$

where $Z_u(t)$ is the upstream water level in the t month, and H_u is the design upstream water level before dam.

The dam project schedule is affected by the flood process and the effusion ability of diversion structures. In order to get the upstream water level random distribution, the uncertainties of flood characters and the discharge hydraulic conditions should be considered, and random flood routing calculation be employed to get the result (Zhong 2005).

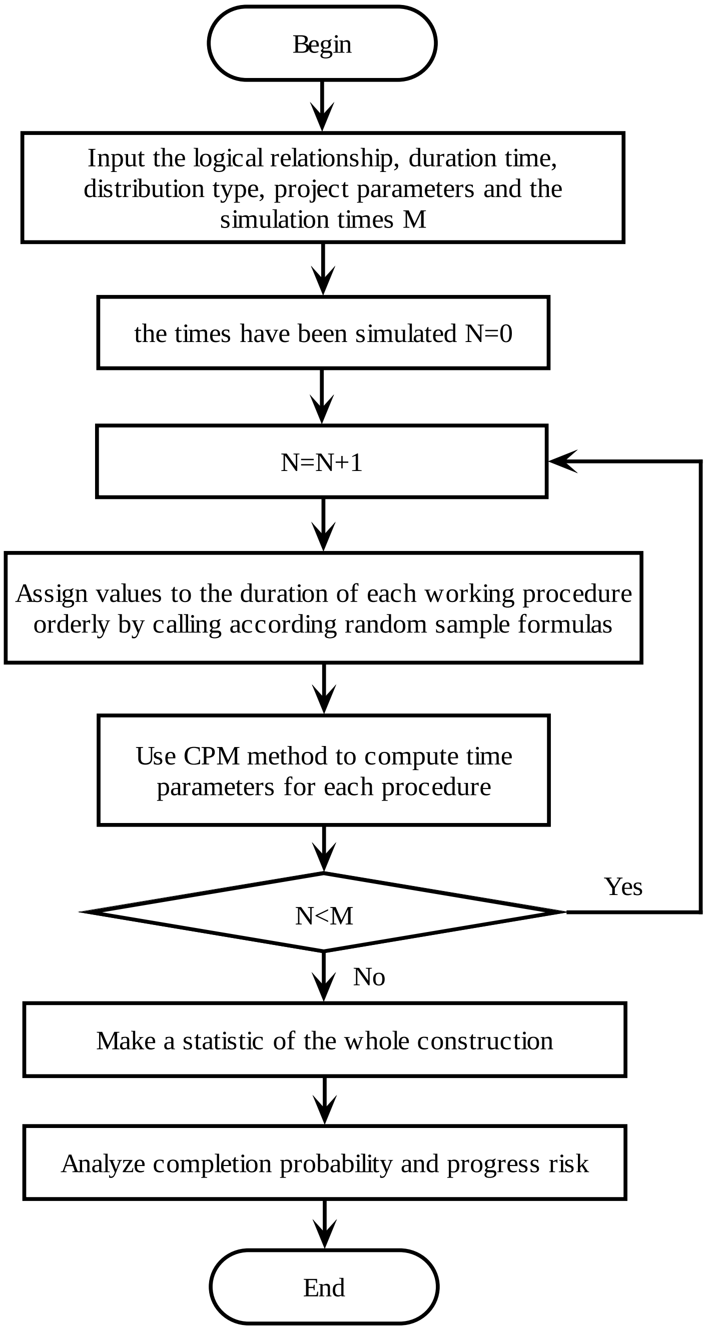


Figure 1: The flowchart of construction schedule risk by Monte-Carlo simulation method

The flood peak values subject to P-III distribution in general hydrology calculation (it is recommended by the Chinese national standard). Using peak values to amplify typical flood process and other hydrology random factors are ignored. Since discharge abilities of discharge structures are affected by kinds of random factors, only the channel roughness factor on discharge abilities is taken account for its remarkable degree, and follows the triangle distribution on the assumption. Other hydropower factors are ignored in the random simulation model. The simulating flowchart of assurance rate of dam construction schedule by Monte-Carlo method is shown as Figure 2.

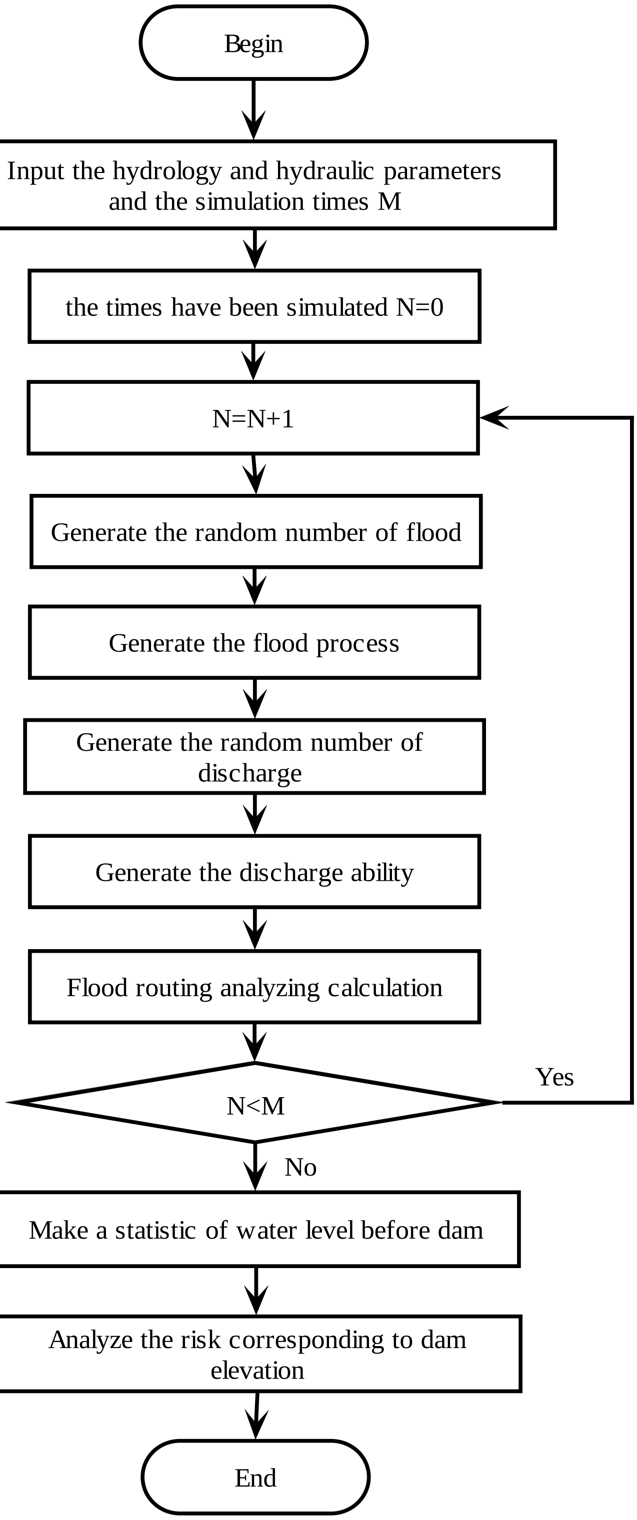


Figure 2: The flowchart of assurance rate of dam construction schedule by Monte-Carlo simulating method

ANALYSIS OF HYDROPOWER DAM CONSTRUCTION PROGRESS COMPREHENSIVE ASSURANCE RATE

Analysis of the uncertainties of construction progress network

During the process of dam construction, schedule curve of the dam H-T_p is usually used to show the relationship between the practical dam elevation and the design schedule, as Figure 3 shows. H_1, H_2, H_3 is the control elevation of dam construction in the following figure.

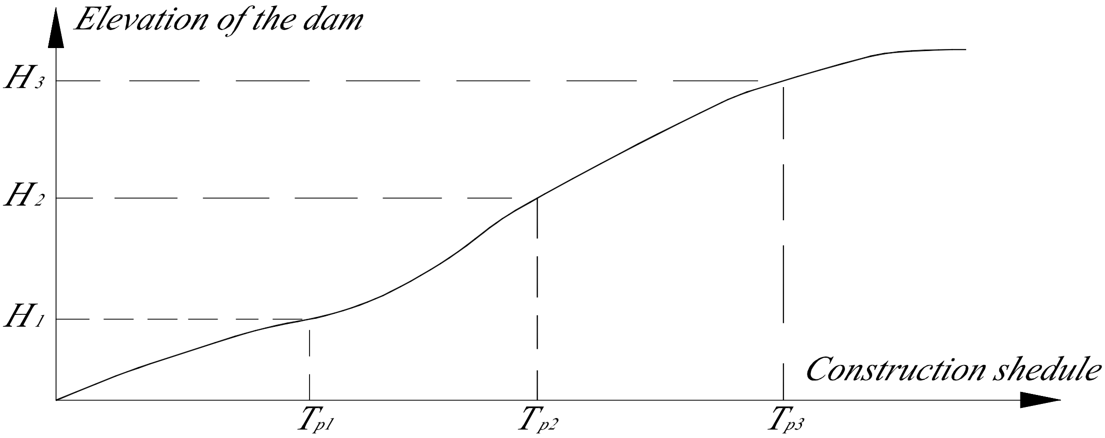


Figure 3: The schedule curve of the dam image

According to the definition of construction schedule risk P_r, we can define the completion assurance rate of construction schedule as:

$$R_T = 1 \Phi P_r, \quad R_T = P(T_C \mathrm{A} T_p) \tag{3}$$

where T_c is the practical / simulation construction schedule; T_p is the plan schedule.

As a specified dam project, based on Monte-Carlo simulation analysis of planning schedule network, it is risky that dam reaches a specified elevation in the specified completion date. The completion assurance rate curve R_T-T_p for each procedure is drawn. The dam elevation H is correspondent to completion assurance rate R_T, as the H growing, the construction are getting more, the uncertain factors impacting on construction are getting more and more, thereby the completion assurance rate of dam is getting lower. Figure 4 is the construction procedure completion assurance rate curve of reaching the elevation H_1.

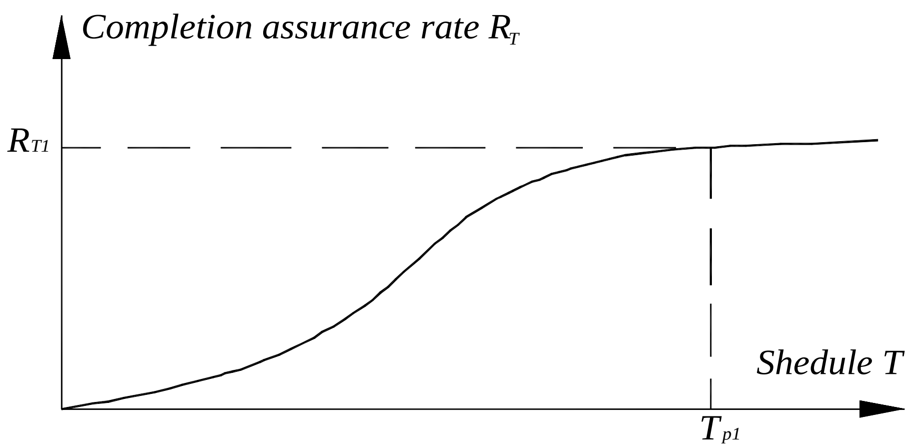


Figure 4: Control elevation H_1 completion assurance rate curve

The relationship between the dam elevation H_1 and completion assurance rate R_T is shown in Figure 5.

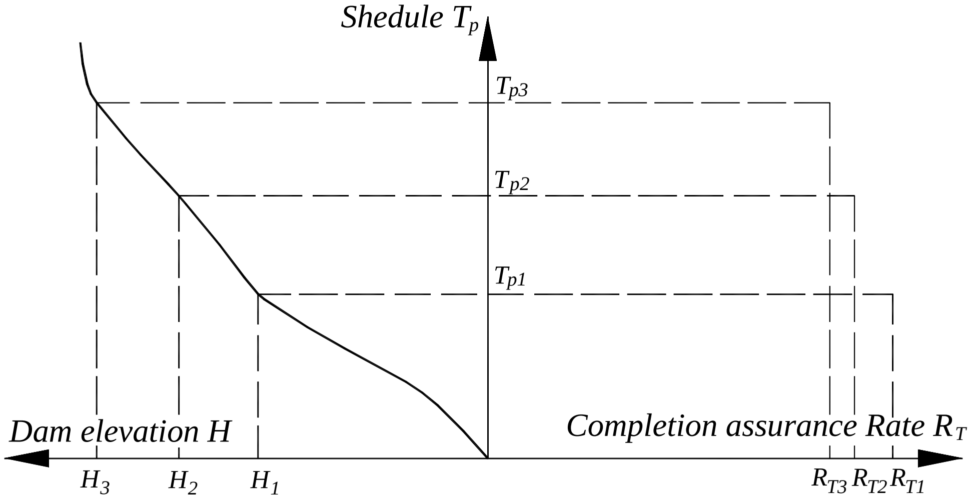


Figure 5: The relationship of the dam elevation *H* and completion assurance rate R_T

The flaw of assurance analysis on dam schedule
Dam schedule assurance R_Q is calculated by a certain designed water lever before-dam, which deems that the height of dam H_{dam} referring to the designed water level can be achieved within the time limit certainly. However, the random features of working procedure duration make uncertainties of the project schedule network. In fact, there is a risk of the dam reaching the specified height within the time limit. Therefore, it is not wise to calculate with a fixed H_{dam} value.

The comprehensive assurance rate of hydropower project construction schedule
Based on the previous analysis, if *R* is the assurance rate of hydropower project construction schedule, *H* is a certain specified height in the project schedule, then the assurance rate of dam schedule R_Q can be presented as $R_Q = f(R|H)$, and assurance rate of reaching specified elevation R_T can be presented as $R_T = f(H)$.

According to the conditional probability formula, there is: $f(R) = f(R|H)\,f(H)$. The standard of comprehensive assurance rate of project schedule is shown as:

$$R_Z = f(R) = f(R|H)\,f(H) = R_Q \times R_T \tag{4}$$

R_Z comprehensively reckons the uncertainties of the hydrology and hydraulic factors in the diversion process, as well as the uncertainty of the project schedule, and supplies the flaws using of R_T and R_Q independently, and thus provides a more reasonable way to evaluate the risk factors in the project process and more effective way to show the assurance rate of project schedule.

INSTANCE OF PROJECT

There is a hydropower project with a clay core rock fill dam as main retain water structure, left bank open spillway, left bank discharge tunnel, right bank discharge tunnel, downstream bank protection and left bank underground diversion system and hydropower station etc. The installed capacity of the station is 5850MW, and the capacity of the reservoir is about 225×10^8m^3. The elevation the dam top is 820.0m, the height of the dam is 261.5m, the normal sluice elevation is 812m, and dead water elevation is 760m. In the initial term diversion it is adopted that river would be closured in one session, earth-rock fill cofferdam retains water for whole year, and tunnel discharges flood.

Based on practical and experience, the channel roughness the three control parameters for discharge building are taken as (0.014, 0.015, 0.017) (parameters of triangle distribution). Some procedures' parameters are listed in Table 1, and other parameters are omitted for briefness.

Table 1: The some procedures' parameters

Procedure number	**Procedure name**	**Precedence number**	**Duration distribution (d) N(μ, σ) [min, max]**
0	start	-	0
1	Spillway bucket lip segment earth and sand-gravel excavation	0	N(93□12.6)[78□110]
2	approach channel earth and sand-gravel excavation	0	N(62□9.8)[50□78]
3	approach channel, weir shutter rock excavation	2	N(145□30.6)[128□176]
4	Channel excavation, underground excavation	3	N(30□5.6)[25□38]

For the result precision, based on construction schedule simulation model with Monte-Carlo method, 400 construction periods are gained by 400 times simulation. The minimum construction period is 3447days (11 years and 2 months), and the maximum is 3509 days (11years and 8 months). The average is 3439 days (11 years and 5 months), the average variance of which is 27.7 days. The completion assurance curve can be found in Figure 6; the construction period assurance rate R_T of 11.5 years design scheme is about 71.8%.

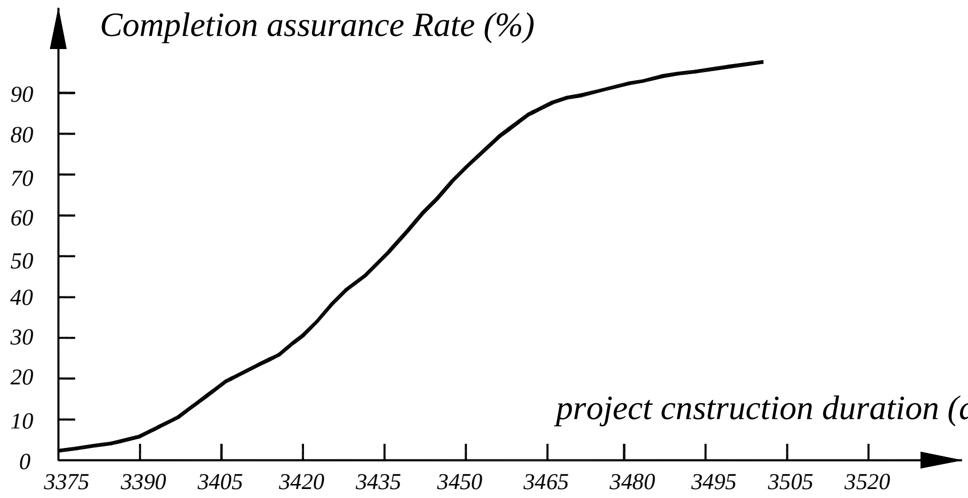


Figure 6: The completion probability curve of the whole period

The preconditions of generating electricity are that reservoir impoundment reaches the design elevation and the generator sets have been built up. The completion assurance rate of primary impoundment period is showed in Figure 7; the assurance rate of the reality of the construction period R_T corresponding 11.5 years (2493 days) is 81.5%.

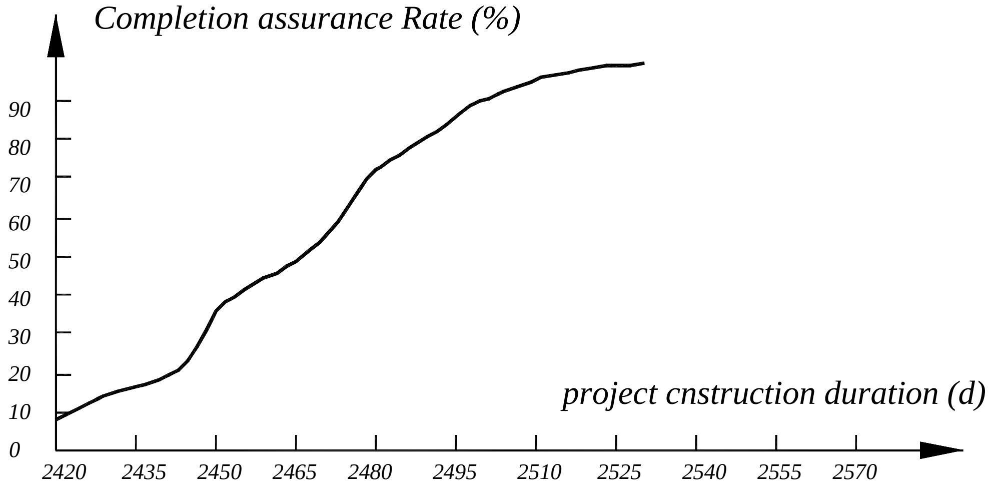


Figure 7: The completion probability curve of initial impoundment

The completion assurance rate of the first generator set generating electricity is showed in figure 8, the realizing assurance rate corresponding to the design construction period R_T 11.5 years (2575 days) is 72.5%.

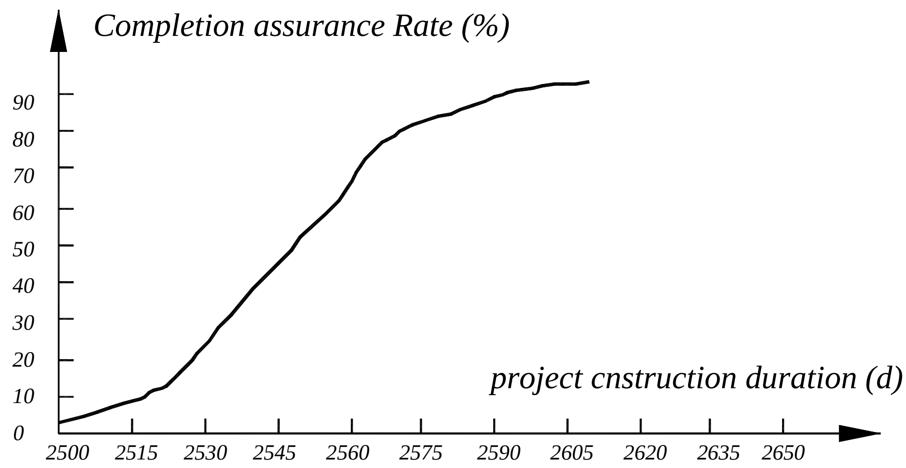


Figure 8: The completion probability curve of the electricity generating period of the first turbine generator set

Table 2: The simulation risk on design water level

Flood return period (year)	Upstream water level by design (m)	Hydrology random		Hydrology and hydraulic random	
		Risk	Assurance	Risk	Assurance
200	672.75	0.335%	99.666%	0.314%	99.686%
300	677.94	0.184%	99.816%	0.182%	99.818%
500	807.12	0.077%	99.923%	0.058%	99.942%
1000	808.67	0.012%	99.988%	0.014%	99.986%

According to hydrology series, the size of diversion structure, construction duration and hydrology and hydraulics etc., uncertain factors, and referring the planning, once the dam raises to 680m elevation in the sixth year before the flood, the dam begin to retain water, this period is called midterm diversion. In this period, the return period of design flood is 200 years, and corresponding flood peak flow is 22000m^3/s. The return period of exceptional flood is 300 years, and the corresponding flood peak flow is 23400m^3/s. In the late term diversion, which is 9th year, the flooding return period is 500 years, corresponding flood peak flow is 25100m^3/s; the exceptional flood is 1000 years, corresponding flood peak flow is 27500m^3/s.

As shown in Table 2, midterm diversion, the dam elevation comes to 680m, and reservoir impoundment. Taking into account of hydrology and hydraulic risk in the diversion period, the possibility that the upstream water level is lower than dam elevation at that time is schedule assurance rate R_Q, is 99.686%. When the elevation of the dam comes to 812m, the first generator set generates electricity. In the late term diversion, flood return period is 500 years and schedule assurance rate R_Q is 99.942%.

Take the uncertainty of construction schedule duration and hydrology and hydraulic risk into account, initial impoundment comprehensive assurance rate:

$R_Z \quad R_T \times R_Q \quad 81.5\% \times 99.686\% \quad 81.24\%$

The comprehensive assurance rate (the first generator set generating period):

$R_Z = R_T \times R_Q \quad 72.5\% \times 99.942\% \quad 72.46\%$.

CONCLUSION

Based on analysis of construction schedule risks and dam construction assurance, taking account of the uncertain factors of hydrology, hydraulic and construction schedule duration, the concept of comprehensive assurance of construction schedule for hydropower project is promoted. A case shows that the comprehensive assurance is smaller than schedule assurance deduced from either construction network schedule uncertainty or hydrology and hydraulic risks. It is shown that the comprehensive assurance of hydropower project construction schedule can represent the risk in the construction process more comprehensively and reasonably.

REFERENCES

Bonnal, P, Gourc, D and Lacoste, G (2004) Where do we stand with fuzzy project scheduling? *Journal of Construction Engineering and Management*, **130**(1), 114–23.

Guo Qiu, L, Maher, M and Wamuziri, S (2001) Risk analysis in construction networks using a modified stochastic assignment model. *Civil Engineering and Environmental Systems*, **18**(3), 215–41.

Hu, Z, Liu, Q, He, C, Fu, Z, Li, D and Zheng, J (2002) Risk analysis of retaining rockfill cofferdam for diversion based on the Monte-Carlo method. *Advances in Water Science*, **13**(5), 634–8.

Hu, Z, Xiao, H and Xiang, C (1999) Approach of fuzzy network planning and its duration possibility for a project construction. *Journal Wuhan University of Hydraulic & Electric Engineering*, **32**(5), 6–9.

Lee, D-E (2005) Probability of project completion using stochastic project scheduling simulation. *Journal of Construction Engineering and Management*, **131**(3), 310–18.

Lu, M and AbouRizk, S M (2000) Simplified CPM/PERT simulation model. *Journal of Construction Engineering and Management*, **126**(3), 219–26.

Wang, Z and Chen, D (1999) Risk analysis of construction schedule for water resource projects. *Journal of Hohai University*, **27**(4), 84–7.

Wang, Z, Yang, G, Yang, J and Shen, Z (2002) Study on completion probability with PERT for hydropower construction. *Journal of Hohai University* **30**(1), 44–8.

Xu, Z and Feng, Y (1998) Schedule risk analysis for network planning. *Systems Engineering - Theory & Practice*, (4), 24–8.

Zhong, D, Liu, K and Yang, X (2005) Uncertainty analysis for construction scheduling with flexible network simulation. *Systems Engineering - Theory & Practice,* (2), 107–12.

AN S-CURVE BAYESIAN MODEL FOR FORECASTING PROBABILITY DISTRIBUTIONS ON PROJECT DURATION AND COST AT COMPLETION

Byung-cheol Kim[1] and Kenneth Reinschmidt

Texas A&M University, 3136 TAMU College Station, Texas, TX77843-3136, USA

Forecasting is a critical component of planning, controlling and risk management for construction projects. In order to support effective project execution and control, project managers must be able to make reliable predictions about the final project duration and cost of projects starting virtually from project inception. The objective of this research is to develop probabilistic forecasting models that integrate all relevant information and uncertainties into consistent predictions in a mathematically sound procedure usable in practice. A Bayesian adaptive forecasting framework using S-curves has been developed. The primary advantages of this new approach against conventional methods such as the critical path method and the earned value method are threefold. It is (1) a probabilistic method that provides confidence bounds on predictions; (2) a consistent method that is applicable to both schedule and cost forecasting; and (3) an integrative method that maximizes the value of information – subjective or objective – available from standard construction project management practice. A numerical example is presented to show the adaptive nature of the new method along with the advantages of a probabilistic approach compared to deterministic methods. In the example, the Bayesian model averaging technique is used to combine predictions by different S-curve models and the results indicate that combined predictions outperform individual predictions.

Keywords: forecasting, project control, project management, scheduling, S-curves.

INTRODUCTION

Project engineers and managers are constantly seeking some indicators that will give them early warning of how well their projects are going based on the predicted cost and duration for completion of individual tasks and complete projects. Such predictions need to be revised and compared with the scheduled completion date and the available budget. The effectiveness of project controls relies on the capability of project managers to forecast final cost and completion time with acceptable accuracy and in a timely manner. One must make the best use of the information being generated by the project itself, in order to forecast its future. Now that most projects, and all major projects, are computerized, there arises the opportunity to make better use of the information being captured by these systems to forecast the future of the project.

Adequate methods to do this are lacking, because the existing methodologies for project performance forecasting, for example, the critical path method (CPM) and the earned value management system (EVM), are almost entirely deterministic and fail to

[1] man2020@tamu.edu

account for the inherent uncertainty in forecasting and project performance. Those methods do not provide confidence bounds on predictions, which are essential to efficient decision making under uncertainty. In addition, the traditional methods do not provide consistent frameworks for both schedule and cost forecasting, and are based on inconsistent assumptions on the relationship between past and future performance. For example, the EVM provides some simple rules for forecasting the estimated cost at completion (EAC) from the budget at completion (BAC) and the cost performance index (CPI), but these are typically linear extrapolations – assuming, for example, that the CPI, which has changed in the past (or it would always equal 1.00) will not change in the future. The CPM predicts the time at completion given a delay in some critical path activity, but typically assumes that delays that affected past activities will not affect future ones. Furthermore, EVM schedule forecasting formulas have been criticized for systematic distortion in the estimated duration at completion by researchers (Short 1993; Vandevoorde and Vanhoucke 2006) and practitioners (Lipke 2003; Leach 2005; Sparrow 2005). As a result, a common practice in the project management community is to use EVM for forecasting EAC and the CPM for managing schedule performance (Fleming and Koppelman 2006; Lipke 2006).

The Bayesian adaptive forecasting model proposed in this research is a probabilistic framework for forecasting project progress and posterior probability distributions on project duration and cost at completion. The ultimate goal of this new approach is to provide decision makers with objective and refined forecasts in a timely manner, which can be used to grasp the current performance more clearly, to forecast the future progress more reasonably and to identify potential measures to improve the chance of successful project completion. Bayesian inferencing, or the revision of beliefs about future activities based on the information gained about past activities, offers a number of opportunities for making more reliable forecasts of future outcomes – and for making reliable forecasts sooner, when they are more valuable to project management. In a general framework of Bayesian inference and forecasting, the proposed method combines all relevant information concerning future performance of an ongoing project, including prior subjective information, baseline progress and its associated uncertainty, and actual data on project progress. For example, Bayesian inference is used to permit prior subjective probability estimates to be combined with actual data on project progress to yield the best estimators of time and cost at completion. The final result is a set of probability distributions on project duration and cost at completion, which are updated as more progress data are reported.

It should be noted that the new method can be applied to forecasting cost performance as well as schedule performance of projects as long as the performance is measured in terms of cumulative progress metrics that show S-like patterns. However, this paper focuses on schedule performance forecasting. Application of the proposed method to cost predictions is straightforward.

EVM PERFORMANCE METRICS

The primary data that should be relied on for predicting future performance of a project are past performance data observed in the project. Recently, EVM has been recognized as a viable method for measuring and controlling project performance, and in use by many public agencies (its use is mandated by NASA, DoD, DOE, and others) and by private owners and contractors to evaluate complex projects. It has the advantage of being universally applicable over a wide range of project types and sizes, because every project, no matter how large or complex, is represented by the three functions: the planned value (PV or the budgeted cost of work scheduled), the earned value (EV or the budgeted cost of work performed), and the actual cost (AC or the actual cost of work performed). Graphical representations of these fundamental functions at time *t* are shown in Figure 1.

The Bayesian adaptive model uses the three performance variables in typical EVM as actual performance data. The project cost and duration at completion predicted at time *t* are updated in terms of the estimated cost at completion (EAC(*t*)) and the estimated duration at completion (EDAC(*t*)), respectively (Figure 1). It should be noted that since the new forecasting method uses the EVM metrics as the primary performance measures, it is focusing on the summary level project progress rather than individual work packages. Any type of progress measure can be used in the new method, not just the EVM metrics. However, we will use the EVM metrics to stand for any progress relation that is monotonically non-decreasing.

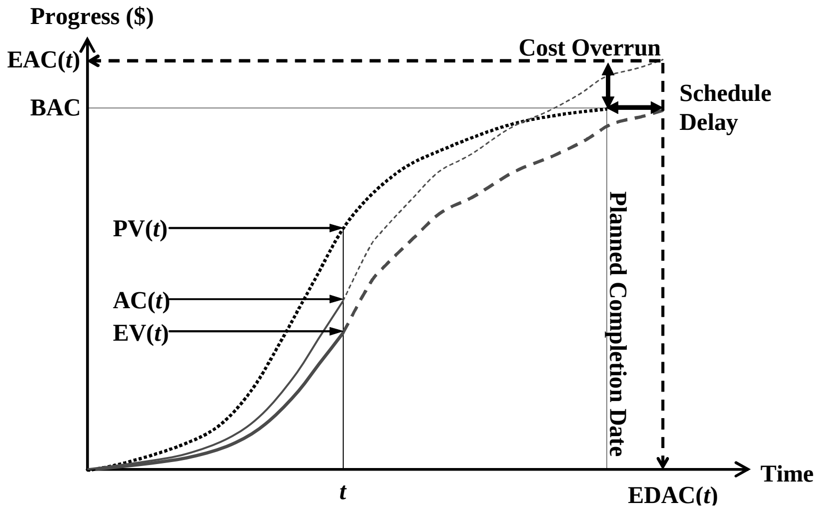


Figure 1: The earned value management metrics

BAYESIAN ADAPTIVE MODEL

Model outline

Bayesian adaptive forecasting (BAF) is a regression model that fits S-curves to actual progress data and updates the parameters of the S-curves using Bayesian inference. Bayesian inference is used to combine prior subjective information with actual data on project progress to yield more reliable estimates of project duration and cost at completion. The Bayesian forecasting approach starts from the premise that there exist typical progress patterns that represent the characteristics of individual projects, such as resource distribution over the project life cycle. The challenges in applying the Bayesian adaptive forecasting method are to identify the unknown actual progress pattern and to fit it to actual performance data available at the time of forecasting.

The outline of BAF is shown in Figure 2. The BAF consists of three procedures: model selection, parameter updating and forecasting. We first obtain from the project plan the prior progress curve, for example, the planned value distributed over time, as determined by the resource-loaded schedule for the project or task under consideration. Then we approximate this set of planned values by fitting some S-curve functions to the points. If the fit of the function to the planned progress is reasonably good, then we can use the function to represent the planned curve, and generate revised curves in the same family by varying the parameters (typically two or three).

What makes this model original is the use of multiple S-curves in project progress predictions combined with the Bayesian approach to updating probability distributions of model parameters. As a result, the prior progress curve can be defined in either a deterministic or a probabilistic way.

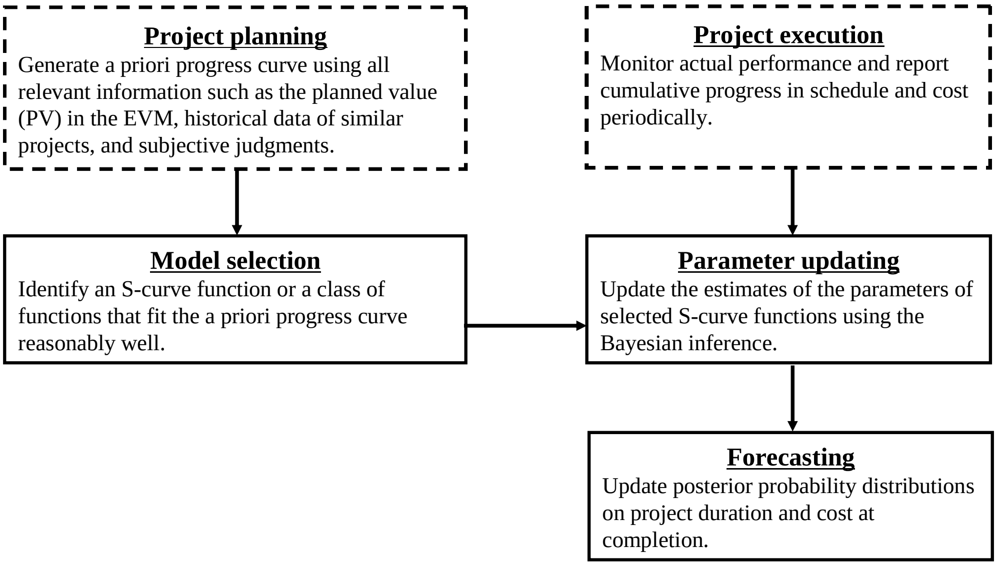


Figure 2: The outline of the Bayesian adaptive forecasting framework

S-curve progress models

An S-curve in project management is a cumulative progress curve that represents the amount of work done or to be done by a specific time throughout the execution phase. Typical cumulative progress curves of projects show S-like patterns, regardless of the unit of measurement, for example, cumulative costs, labour hours, or percentage of work (PMI 2004). The S-curve is a universal characteristic of all projects, regardless of the type, size and complexity of a project.

To generate an S-curve of a project, we need the project schedule and budget allocated to the activities. Then a point on the S-curve at a specific time is the amount of work to be done by that time. Many projects are actually managed by the S-curves. However, previous studies of the use of S-curves as a quantitative tool, not just a visual display, are very limited (Murmis 1997; Barraza *et al.* 2000, 2004; Cioffi 2005). Murmis (1997) generated a symmetric S-curve from a normal distribution and forced it to pass through fixed points of the cumulative progress curve. Murmis applied the curve to detect problems in project performance. A more flexible S-curve was presented by Cioffi (2005). He modified a typical sigmoid curve used frequently in ecology by imposing three project boundary conditions: zero-initial state, the slope of the rise in the S-curve, and the time at which half the total work has been completed. Barraza and his co-researchers (2000, 2004) tried to use a set of S-curves generated from a Monte Carlo simulation program as a visual project control tool. Useful as they are, these previous works are not applicable to the current research of forecasting at-completion project duration and cost of ongoing projects, largely because of poor flexibility of the suggested S-curves and the lack of forecasting algorithms based on actual performance information available at the time of forecasting.

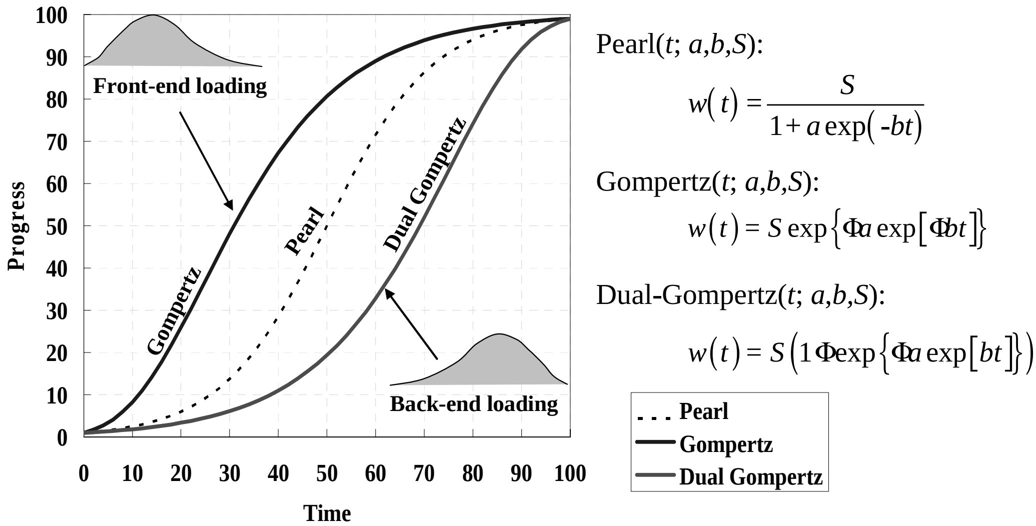
Experience has shown that most projects and project tasks follow sigmoidal patterns, but the individual shapes vary, and so no universal function has been yet found that fits all projects and tasks. Therefore, to apply this method of forecasting, it is necessary to have available a set of functional forms that can be trial-fitted to the dataset. Some basic S-curve models are shown in Figure 3. The Pearl and Gompertz belong to logistic functions that have many application areas in biology and economics. The Dual-Gompertz function is a modified form of the Gompertz to represent the progress of a project with back-end loading. As mentioned earlier, the accuracy and reliability of the BAF depend heavily on finding a mathematical function or functions that represent the planned progress reasonably well. Therefore, a reasonable way of improving the quality of predictions from the BAF is to start with many diverse S-curve functions and to screen them in an effective and systematic way. In an effort to enrich the library of mathematical S-curves, two original S-curve models, which are termed ‘Function 46’ and ‘Function 50’, were developed by the second author of this paper and successfully used in the numerical example in this paper.

Function46(t; n,b,S):

$$w(t) = S\left[\frac{b\,\Phi t}{b}\right]^{n+1}\left[\left(\frac{b\,\Phi t}{b}\right)(n+1)\,\Phi(n+2)\right] + S$$

Function50(t; n,b,S):

$$w(t) = S\left[\frac{(n+3)(n+2)(n+1)}{2b^2}\right]\left[\frac{b\,\Phi t}{b}\right]^{n+1}\left[\frac{2b(b\,\Phi t)}{n+2}\,\Phi\,\frac{(b\,\Phi t)^2}{n+3}\,\Phi\,\frac{b^2}{n+1}\right] + S$$



Pearl(t; a,b,S):

$$w(t) = \frac{S}{1 + a\exp(-bt)}$$

Gompertz(t; a,b,S):

$$w(t) = S\exp\left\{\Phi a\exp\left[\Phi bt\right]\right\}$$

Dual-Gompertz(t; a,b,S):

$$w(t) = S\left(1\,\Phi\exp\left\{\Phi a\exp\left[bt\right]\right\}\right)$$

Figure 3: Examples of S-curve functions when $w(0) = 1$, $w(100) = 99$, and $S = 100$

Updating model parameters using Bayesian inference

The parameters of an S-curve model are estimated and updated through Bayes’ law whenever new actual performance data become available. If a project manager has an initial estimate of project progress (that is, a project plan) and if this progress curve is fitted to some known model with associated parameters (ς), the belief in the individual model parameters can be updated with actual performance data (D) as the project proceeds. Bayes’ law for this case can be written as:

$$P(\varsigma \mid D) = \frac{P(D \mid \varsigma)P(\varsigma)}{P(D)} \tag{1}$$

where $P(\Theta)$ is the *prior distribution* reflecting the belief in parameters before observing new outcomes; $P(D|\Theta)$ is the *conditional probability* that the particular outcomes *D* would be observed, given the parameters Θ; $P(D)$ is the marginal distribution of the observables *D*; and $P(\Theta|D)$ is the *posterior distribution* of the parameters Θ given that the outcomes *D* were observed.

Formulation of the Bayesian adaptive forecasting model

For an S-curve function with *m* parameters, the Bayesian updating process proceeds as follows. Let Θ denote the set of parameters $\{\theta_1, \theta_2, ..., \theta_m\}$. We choose parameters independently so that the prior probability distribution of the parameter set is represented as

$$p(\Theta) = p(\theta_1)\, p(\theta_2) \cdots p(\theta_m) \tag{2}$$

Once a project gets started, actual progress is reported periodically and the data can be represented as a series of discrete values *D*.

$$D : (w_i, t_i),\ i = 1, ..., N \tag{3}$$

where w_i represents the cumulative progress reported at time t_i and *N* is the number of records up to the time of forecasting.

The likelihood of the data conditional on the parameters chosen is measured based on the errors between the actual times of performance reporting and the planned times determined by a specific S-curve model and the parameters, $T_M(w_i | \Theta)$. We seek an S-curve model and its associated parameters that make the errors normally distributed with zero mean and standard deviation σ. It is assumed that the random errors corresponding to different observations are uncorrelated. Then the likelihood of the data conditional on the parameters is calculated as the product of the likelihood of each observation.

$$p(D|\Theta) = \prod_{i=1}^{N} p(t_i, w_i | \Theta) = \prod_{i=1}^{N} \frac{1}{\sqrt{2\pi}\sigma} \exp\left[-\frac{1}{2} \left(\frac{t_i - T_M(w_i | \Theta)}{\sigma} \right)^2 \right] \tag{4}$$

It should be noted that the value of σ is determined by decision makers or forecasters to adjust the sensitivity of predictions to the actual data reported.

The marginal distribution of the observables *D* is determined from

$$p(D) = \int p(D, \Theta)\, d\Theta \tag{5}$$

where the joint probability distribution of data and parameters is constructed from Equations 2 and 4 as $p(D, \Theta) = p(D|\Theta)\, p(\Theta)$.

The ultimate goal of the Bayesian approach to prediction problems is to obtain a posterior marginal distribution of each model parameter conditional on the observed data. Using fundamental properties of conditional distribution, the posterior marginal distribution of parameter θ_i can be derived by integrating the joint parameter distribution conditional on the observed data, which is determined from Equations 1 to 5, with respect to the remaining parameters ($\theta_1, \cdots, \theta_{i-1}, \theta_{i+1}, \cdots, \theta_m$).

In the Bayesian adaptive forecasting framework, *a priori* information from various sources is taken into account in terms of prior distributions of model parameters. Table 1 summarizes some examples of additional performance information that can be used as inputs.

Table 1: Additional information used in the Bayesian adaptive forecasting method

Types	Descriptions
Project activity network **G** = G(*n*, *r*)	A project activity network is represented as a directed acyclic network G(*n*, *r*), where *n* is the number of activities in the network and *r* is the number of Finish-to-Start relations among the activities.
Activity durations and costs **A** = {a_1, a_2, …, a_n}	Each element of the information set, **A**, has probabilistic estimates of an activity duration and cost.
Historical progress information **H** = {h_1, h_2, …, h_m}	A historical dataset might be represented as a series of discrete performance indicators. *m* is the number of historical progress datasets.
Subjective information **S** = {c_1, c_2, …, c_s}	*s* is the number of subjective information sets that can be chosen by decision makers. In the proposed methodology, a subjective information set is represented in terms of numerical constraints for the model parameters.

NUMERICAL EXAMPLE

An artificial project has been analysed to demonstrate the performance of the new Bayesian adaptive forecasting model. First, a random activity network of a project with 200 activities and 279 precedence relations is generated using a random network generation method augmented with a redundancy elimination technique. Then, Monte Carlo simulation is carried out to determine the planned progress curve and the prior probability distribution of the completion date. The completion dates and corresponding progress curves for a set of random activity durations are calculated with the early start forward calculation in CPM. It is assumed that all activities in the project are homogeneous with the same stochastic properties in duration and cost. This homogeneous assumption is based on a scheduling practice in which activities in a project network are defined in such a way that they are just small enough to be managed effectively, and not too small to cause additional burdens in management.

The planned progress and the simulated ‘actual’ progress used in the numerical example are shown in Figure 4. From a Monte Carlo simulation based on a random activity network and the assumed probability distributions of activity durations and costs, the prior distribution of the completion date is estimated to have the mean of 71 weeks and the standard deviation of 6.6 weeks. The planned progress curve in Figure 4 is determined by averaging stochastic progress curves from 5000 iterations over the progress dimension. The dotted line represents a simulated progress curve with completion date at 79 weeks. The simulated curve is generated from the same network schedule for the planned progress curve. Therefore, the curve represents an ‘actual’ progress of the project, which is determined at random owing to the uncertainty in the assumed activity durations and costs. It should be noted that, although the complete actual progress is determined in advance, the actual performance data are assumed to be available only after each reporting period up to the time of forecasting.

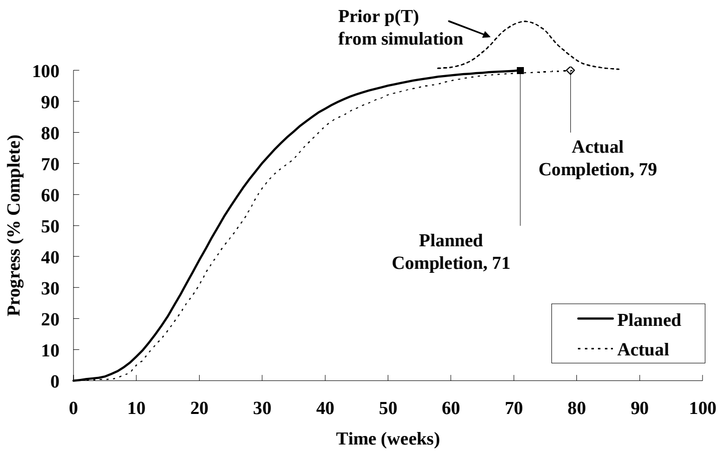


Figure 4: The simulated 'actual' progress curve and prior information from a random activity network, **G**(200,279), and the assumed activity information, **A** = $\{a_1,\ldots,a_{200}\}$

The five S-curve functions discussed earlier are fitted to the planned progress curve. The least squares method is used to measure the goodness of fit and four functions other than the Dual-Gompertz function fit the planned progress curve reasonably well. The fitted graphs are shown in Figure 5 and the corresponding prior estimates of the model parameters are shown in Table 2. It should be noted that the prior distribution of the completion date, which is obtained from the network-based schedule simulation, is also taken into account in terms of a random variable T in the formulas for slope parameter b. The results show that the Gompertz function best fits the current planned progress with the minimum sum of the squares of vertical deviations.

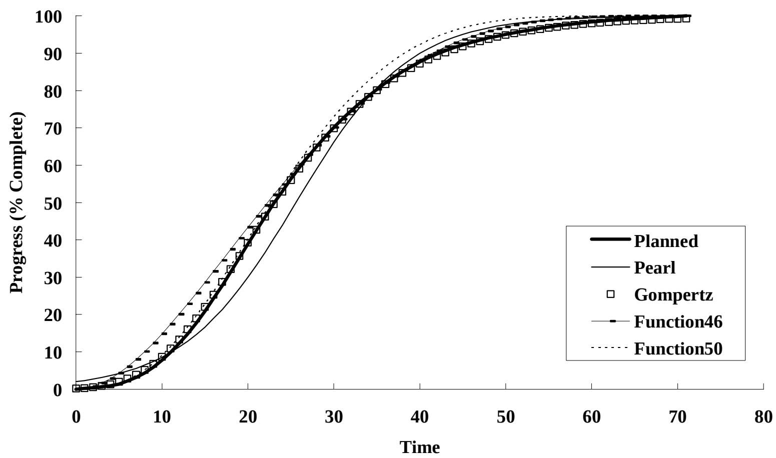


Figure 5: S-curve functions fitted to the planned progress

Table 2: Prior estimates of model parameters

	Parameters for shift (*a*) or shape (*n*)	**Slope parameter (*b*)**	**Sum of the squares of vertical deviations**
Pearl	a = 49.0	$[\ln(49) - \ln(1/49)]/T$	1102
Gompertz	a = 6.377	$[\ln(6.337) - \ln(0.00702)]/T$	23
Function46	n = 3	T	765
Function50	n = 5	T	520

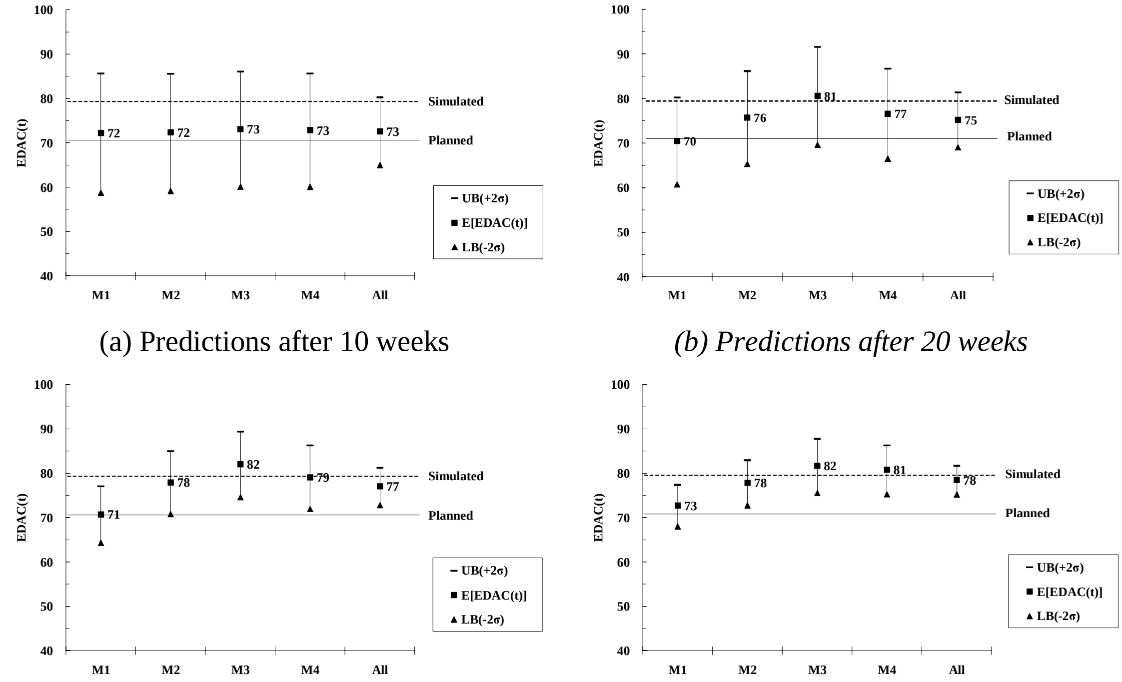
With the prior estimates of model parameters and weekly performance reports, EDAC is calculated after 10, 20, 30 and 40 weeks using the four S-curve functions. The results are shown in Figure 6. Different predictions from different models are combined with weights according to the relative reliability of the models, which is determined as the marginal probability of observing actual performance data conditional on each model. The predictions at week 10 show that all models provide similar results that are close to the prior estimates of completion date. This is attributed to the fact that the Bayesian adaptive model uses both prior information and actual progress data, and the prediction is influenced more by the plan than it is by the small number of data points reported up to this time.

The other three graphs in Figure 6 show the adaptive nature of the BAF. Undoubtedly the forecast would be repeated after every reporting period to incorporate the new data, but here the intermediate updates have been omitted. Comparing the forecasts at different points of project execution, it is easy to see that each model responds to the actual performance data in a different way. After 20 weeks, predictions by Gompertz (M2), Function46 (M3), and Function50 (M4) move away from the plan and approach the actual completion date, due to the accumulated discrepancies between the actual reports and the planned progress curve. However, it should be noted that the planned completion date is still inside of the confidence bounds that are determined at two standard deviations above and below the expected EDAC. The confidence bounds should be determined in advance by project managers as a level of risk accepted by the owner or organization. As more actual data accrue, the confidence bounds on the predicted values become narrower for all models. After 30 weeks, the combined prediction gets closer to the actual completion date, and more importantly, the confidence bounds indicate that the probability of completing the project within the planned completion date becomes lower than the predetermined acceptable level. Predictions after 40 weeks clearly show these patterns and the combined forecast provides more accurate prediction of the actual completion date than its component forecasts.

CONCLUSIONS

The new Bayesian adaptive forecasting model provides informative and reliable predictions on project duration and cost at completion because it provides confidence bounds on predicted values and *a priori* information and uncertainties in typical construction projects are seamlessly integrated into consistent predictions. For example, a range estimate of project duration before the beginning of a project can be taken into the forecasting process and used to improve the reliability of predictions during the early phase of execution period when project managers often suffer from lack of actual performance data to make decisions about taking controlling actions.

In addition, easy implementation to real projects will make the new method attractive aids for better project schedule and cost management practices. Any projects whose performance is monitored and managed using the EVM can adapt the new methods with almost negligible efforts and cost. The Bayesian adaptive forecasting model is developed as a spreadsheet program such as Excel® and can be easily integrated into the typical earned value management system.



(a) Predictions after 10 weeks

(b) Predictions after 20 weeks

(c) Predictions after 30 weeks

(d) Predictions after 40 weeks

Figure 6: The estimated duration at completion at different times (M1-Pearl; M2-Gompertz; M3-Function46(n = 3); M4-Function50(n = 5))

REFERENCES

Barraza, G A, Back, W E and Mata, F (2000) Probabilistic monitoring of project performance using SS-curves. *Journal of Construction Engineering and Management*, **126**(2), 142–8.

Barraza, G A, Back, W E and Mata, F (2004) Probabilistic forecasting of project performance using stochastic S-curves. *Journal of Construction Engineering and Management*, **130**(1), 25–32.

Cioffi, D F (2005) A tool for managing projects: an analytic parameterization of the S-curve. *International Journal of Project Management*, **23**, 215–22.

Fleming, Q W and Koppelman, J M (2006) *Earned value project management*. 3ed. Project Management Institute.

Leach, L (2005) EVM & critical chain project management. *In*: *NASA project management challenge*. Houston.

Lipke, W H (2003) Schedule is different. *The Measurable News*, 31–4.

Lipke, W H (2006) Earned schedule leads to improved forecasting. Paper presented at the 3rd International Conference on Project Management (PROMAC 2006).

Murmis, G M (1997) ‘S’ curves for monitoring project progress. *Project Management Journal*, **28**(3), 29–35.

PMI (2004) *A guide to the project management body of knowledge*. 3ed. Newtown Square, PA: Project Management Institute, Inc.

Short, J W (1993) Using schedule variance as the only measure of schedule performance. *Cost Engineering*, **35**(10), 35.

Sparrow, H (2005) Integrating schedule and EVM metrics. *In*: *NASA project management*

Vandevoorde, S and Vanhoucke, M (2006) A comparison of different project duration forecasting methods using earned value metrics. *International Journal of Project Management*, **24**(4), 289–302.

USING COGNITIVE MAPS FOR RISK MODELLING IN CONSTRUCTION PROJECTS

Irem Dikmen[1], M. Talat Birgonul and Guzide Atasoy

Civil Engineering Department, Middle East Technical University, Balgat, Ankara 06531, Turkey

Successful management of risk requires identification of risk sources, construction of risk models and preparation of management plans throughout the life cycle of a project so that the project objectives can be met. Risk modelling is a critical step in the risk management process as a risk model is used to simulate the project performance under different scenarios and it constitutes the foundation of a risk management plan. In this paper, major challenges of developing realistic risk models in construction projects are discussed. One of the problems is inconsistent definition of risk sources, consequences and factors that affect the impact of risks on project success. Although some of the individual risk factors may be more significant than the others are, the project success usually depends on the combination of all risks, response strategies used to mitigate risks and a company's ability to manage them. Thus, there exists a need to develop a risk model that contains the interrelations between risks, response strategies and project success criteria. A cognitive map is a qualitative model of how a system operates under different conditions where the conditions are simulated by different values of variables that can be physical quantities or abstract concepts and the causal relationships between them. The potential applications in the risk management domain are basically, risk assessment for the prediction of project success and risk evaluation during post-project appraisal. It is also possible to use cognitive maps for comparison purposes. In this paper, development of risk models with cognitive maps is demonstrated on a real project. The example project is a major highway project amounting to approximately 600 million US dollars carried out by an international joint venture. The cognitive map of a person at the top management level is drawn to model the risk sources, consequences, strategies and project success criteria. Case study findings demonstrate that cognitive mapping may be used as an effective learning tool for risk evaluation.

Keywords: cognitive maps, post-project appraisal, risk.

INTRODUCTION

Risk management (RM) is a formal process for systematically identifying, analysing and responding to risk events throughout the life of a project to obtain the optimum or acceptable degree of risk elimination or control. RM is about definition of objective functions to represent the expected outcomes of a project, measuring the probability of achieving objectives by generating different risk occurrence scenarios and development of risk response strategies to ensure meeting/exceeding the preset objectives (Dikmen *et al*. 2004). RM in construction is a tedious task as the objective functions tend to change during the project life cycle, and the risk scenarios are numerous due to sensitivity of construction projects to uncontrollable risks stemming from the macro-environment, existence of high number of parties involved in the project value chain, and one-off nature of the construction process (Jaafari 2001). In this paper, challenges of risk

[1] idikmen@metu.edu.tr

modelling are discussed and potential usage of cognitive maps is proposed to eliminate some of these challenges.

RISK MANAGEMENT: CHALLENGES

In order to handle the complexities of the risk management process in construction projects, a formal risk management system is necessary. The tools, techniques and information requirements of risk management process shall be defined as a part of the risk management system that has basically three outputs:

- Risk register: it is a risk checklist in which the risk sources are defined together with their expected impacts and probabilities.
- Risk model: it is used to simulate the project performance under different scenarios (in the presence of the identified risk factors).
- Risk management plan: it is an action plan, based on the risk register and risk model, where effective strategies are generated to manage risks.

The success of a risk management plan is dependent on how the risks are identified and modelled. When the literature is investigated, it is clear that there are numerous risk checklists and risk breakdown structures proposed by different researchers. The major drawback in some of these lists is “inconsistency”. The word risk may be used to imply source, consequence or probability of occurrence of a negative event. When risk sources are mixed with consequences, this leads to a major inconsistency and wrong formulation of the risk model. For example, a consequence like cost overrun should be considered on a different platform than sources such as inflation, technical risk or changes in project scope. Another problem is the interdependency between the risk sources. The most widely used risk rating technique based on multiplication of probability with impact is an over-simplistic approach as it is based on the assumption that “risk factors are independent”. There are usually correlations between risks as they may be affected from similar underlying sources. Moreover, in the assignment of ratings (usually using Likert scale), there may be significant differences between the values attached by decision-makers due to different assumptions about “level of controllability”. Some people may consider that the probability of occurrence of a risk factor is low if it is controllable by assuming that necessary precautions will be taken to eliminate them; while others may consider probability of occurrence regardless of response. Thus, some factors that affect the “magnitude of risk” shall be defined explicitly and the interrelations between these factors and risk sources shall be defined clearly.

Another problem related with the risk management process is that risk management plans are usually prepared at the start of the project, usually not revised during the life cycle of the project and not evaluated at the end. The aim of RM should be effective monitoring of risks and project success in order to revise plans, better communication of risk between project participants, construction of a corporate memory to introduce experience-based solutions of how risks can be avoided and, finally, learning from risks. In order to facilitate learning from the actually happened risk events, risk management plans shall be compared with the actual risk consequences and effectiveness of risk management plans shall be evaluated as a part of post-project appraisal. If this comparison can be carried out successfully, lessons learnt about risks may be used as a valuable input for risk management efforts in the forthcoming projects.

Finally, it is a well-known fact that lack of common understanding of the parties about risk sources, response strategies and ownership may affect project success negatively. One of the aims of preparing risk management plans is to increase awareness of project participants about the risk scenarios and risk allocation schemes. The first step to eliminate potential conflicts between the project participants is identification of possible differences in their understanding of the project risk environment. If differences can be revealed at early stages of a project, the probability of having problems due to vagueness in risk allocation schemes can be minimized.

The aim of this paper is to discuss potential usage of cognitive maps (CM) to eliminate some of the above-discussed shortcomings. Cognitive maps may be used to construct better risk models, facilitate learning from risks and reveal differences in mental risk models of different parties.

COGNITIVE MAPS

CMs provide a holistic picture of an individual's overall perspective, without any loss of detail, enabling a decision-maker to move beyond the assumption of internal consistency to the detailed assessment of specific concepts within the map (Clarke and Mackaness 2001). A CM has the ability to reveal an actor's subjective understanding of the dynamics of socially constructed situations. It is a representation of the thoughts and knowledge of people with the usage of diagrams composed of concepts and their relations. The concepts are shown with nodes and the relations between the concepts are represented by arrows showing the direction and sign of causality. If the interrelations between nodes are shown by positive and negative numbers indicating the sign and strength of a relationship, these maps are called as weighted cognitive maps. Kosko (1986) introduced the concept of fuzzy cognitive maps (FCM), which are weighted cognitive maps with fuzzy link values.

CM was first introduced by Axelrod (1976) for political analysis and decision making. It has been used widely by researchers in a variety of different contexts such as management and administrative sciences (Eden 1992; Eden *et al*.1992; Langfield-Smith and Wirth 1992; Smith *et al*. 1995). Recently, CMs have been used in modelling the strategy building process (Carlsson and Fuller 1996), the process of way finding (Chen and Stanney 1999), business redesign (Kwanhk and Kim 1999) knowledge management (Noh *et al*. 2000), design of electronic commerce websites (Lee and Lee 2003) and modelling IT projects success (Rodriguez-Repiso *et al*. 2007). In the construction management literature, there are only a limited number of studies that use the influence diagramming method, which is a special form of cognitive mapping. Influence diagrams have been used by Ashley and Bonner (1987) for political risk assessment; by Poh and Tah (2006) for cost-time integration and by Dikmen *et al*. (2007) for risk modelling of international construction projects.

CMs can be used to deal with complex issues that can hardly be modelled with quantitative reasoning. Eden (2004) suggests the use of CMs to depict and explore the cognitive structures of members of organizations who are facing complex issues. CMs may also be used to acknowledge differences in management views and encourages discussion, suggesting alternative courses of action. Using case studies about IT/IS, Al-Shehab *et al*. (2004) argue that causal mapping may be used as an effective method of documenting past experience. They conducted an exploratory experiment using causal mapping method and reported that CM encourages participation and facilitates group discussions; enhances communication between group members; provides a clear picture of the situation through its diagrammatic representation; and, finally, enables the identification of interrelations between several factors (such as risk, decisions, assumptions etc.).

Its benefits such as drawing a holistic picture of an individual's overall perspective, reflection of managerial perceptions of real world and providing a platform for comparison of different mental models make it an appropriate tool to eliminate some of the above-discussed shortcomings of RM. In the next section, potential uses of CMs for RM will be discussed.

POTENTIAL USES OF COGNITIVE MAPS FOR RISK MANAGEMENT

CMs can mainly be used for construction of individual mental risk models, comparison of risk models drawn by different decision-makers, prediction of risk impacts and learning from previous projects.

As risk modelling necessitates consideration of risk sources, consequences and influencing factors, CMs can be used effectively to demonstrate the causal relations between the concepts. Influence, causality and system dynamics of a project's risk environment can be modelled and a holistic picture of an individual's overall risk perspective can be drawn. CMs can be used either for risk modelling at the start of a project or after project completion. Risk events may be evaluated at the end of a project in order to increase learning from what actually happened in the project. Risk evaluation process can be facilitated by CMs, which can effectively summarize a complex network of variables.

For revealing understanding of concepts related with risk, a CM can be drawn by each project participant. The cross-sectional differences between groups of actors may be revealed and if the differences are due to misunderstanding, wrong assumptions and vagueness of some concepts, they may be tried to be eliminated for a common understanding of the risky situation. CMs drawn before and after the project may be compared to monitor how belief systems change over time. The study of past projects can help to sensitize project participants to the potential problems that may affect the new project's success. Thus, CMs may facilitate learning in an organization.

FCMs (Kosko 1986) can be used to analyse, simulate, test the influence of parameters and predict the behaviour of a system. FCM is a supervised learning neural system that can produce responses from a given set of initial conditions. Thus, if a set of actually happened risk cases are fed into a CM together with their actual outputs, it may learn the relations between the concepts and may predict an output when it is given a set of input conditions such as magnitude of risks, planned strategies, contract conditions etc. The difficulty lies in the fact that as the construction projects as well as the conditions under which they are realized are unique, it is hard to collect enough data about similar cases. If the number of cases is low, FCM may not be able to learn the magnitude of interrelations between the concepts and its prediction ability may be low.

Cognitive maps are usually derived through interviews and so they are intended to represent the subjective world of the interviewee (Eden 2004). Systematic approaches exist for elicitation and comparison of CMs; particularly tools such as Cognizer and Decision Explorer can be used to explore the structure and content of CMs and make comparisons between different maps. In the next section, the utilization of cognitive mapping method for risk evaluation in a construction project is demonstrated by a case study.

AN APPLICATION OF COGNITIVE MAPS TO A HIGHWAY PROJECT

The case study project is a major highway project that includes the construction of two tunnels, four viaducts, three bridges, one overpass and two subways. The project is carried out by an international joint venture (Italian and Turkish contractors) responsible from engineering, design and construction. The contract was signed in 1990 and construction started on 1993. The duration of the project was planned to be 48 months and its estimated cost was around 570 million US $. Actually, it was completed approximately in 14 years (partially opened on January 2007) and costed around 1 billion US $. There was a big public reaction due to the delays and cost overruns of this mega project. The reasons of failure to keep up with time and budget limits are announced to be *force majeure* events (mainly earthquake) and extensive design changes. In this paper, factors that affected the project success will be discussed by referring to the CM of a manager who works in the Italian construction company. The map reflects his perceptions and cannot be interpreted as an objective model of the drivers of success/failure in the case study project.

The CM was drawn as a result of an interview that took around two hours. The interviewee was allowed to talk about the factors that affected the success of the highway project. Every concept he mentioned was written on a piece of paper; at the end of the session, these concepts were shown to him. The majority of the concepts that he identified were problems (risk events, wrong decisions etc.) rather than fortunate events that affected the success of the project. After validation of the completeness of the list of concepts, a preliminary cognitive map was drawn up by the researchers, according to the information gathered during the interview, which was submitted to the interviewee together with an empty adjacency matrix. The adjacency matrix shows the strength of the causal relations between the concepts. The interviewee was requested to check the structure of the cognitive map and fill the necessary values in the adjacency matrix using the given evaluation scale (see Table 1).

Table 1: Evaluation scale

Value	Explanation
1	Very high positive impact
0.8	High positive impact
0.6	Moderate positive impact
0.4	Weak positive impact
0.2	Very weak positive impact
0	No relation
-0.2	Very weak negative impact
-0.4	Weak negative impact
-0.6	Moderate negative impact
-0.8	High negative impact
-1	Very high negative impact

The final list of concepts is presented in Table 2. After the interviewee validated the structure and assigned the link values, the CM was finalized. The final version of the CM for the case study project and adjacency matrix are presented in Figure 1 and Figure 2, respectively.

Table 2: List of concepts

Concept ID	Description
C1	Poor performance of the engineer
C2	Errors in specifications
C3	Political interference/pressure
C4	Economic crisis
C5	Poor geotechnical investigation
C6	Flood
C7	Earthquake
C8	Design changes
C9	New local partner
C10	Suspension of works
C11	Change in the management team
C12	Change orders by the client
C13	Bureaucratic delays
C14	Conflict with partners
C15	Wrong decisions about project management
C16	Poor performance of the subcontractor
C17	Low productivity
C18	Change in scope
C19	Wrong construction method/technology selection
C20	Increase in the amount of work
C21	Delay
C22	Increase in costs
C23	Claims/disputes with the client
C24	Risk adjusted bid price/appropriate contingency
C25	Profitability
C26	Public pressure
C27	Poor reputation
C28	Project success

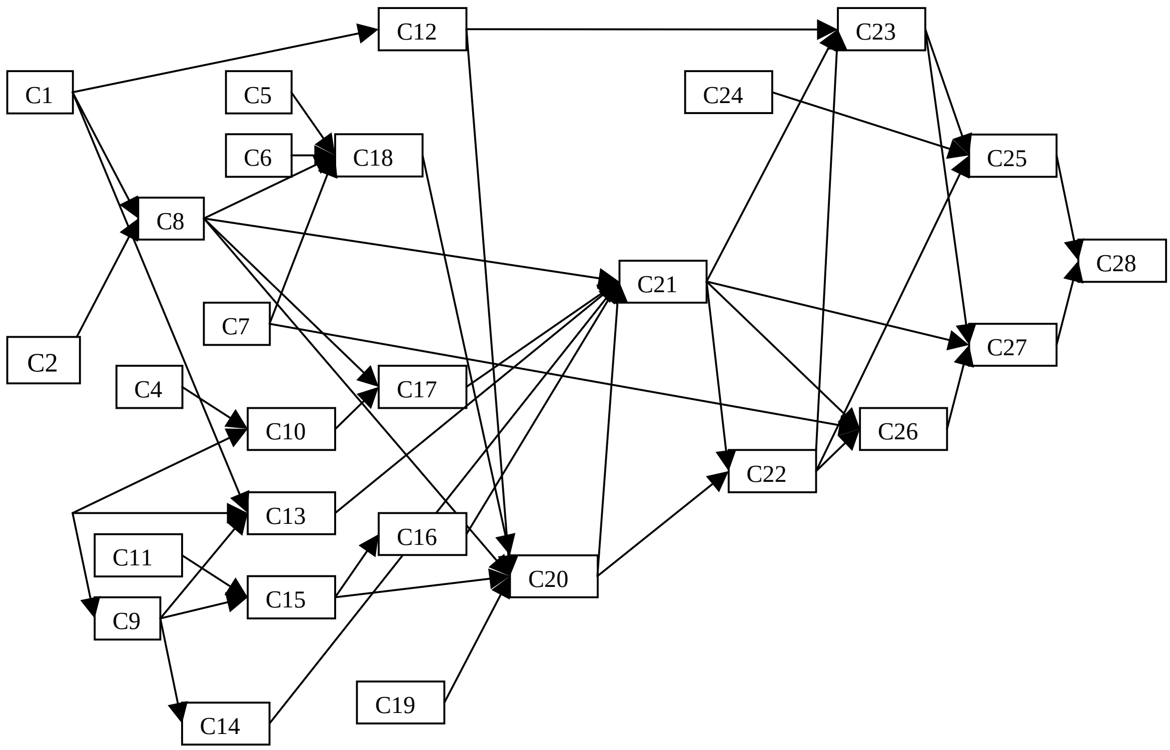


Figure 1: Cognitive map (note: the strengths of relationships are not shown on the map, they are given in the adjacency matrix)

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28
C1	0	0	0	0	0	0	0	1	0	0	0	1	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0	0	0	0.6	0.6	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0.2	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.8	0	0.8	0.8	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	0	0	0	-0.4	0.6	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0
C10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0	0	0	0
C11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0
C12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0.8	0	0	0	0	0
C13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0.4	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0	0	0	0
C17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0
C18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0	0	0	0
C19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	0	0	0	0	0	0	0
C20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.8	0	0	0	0	0	0
C21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.6	0	0	0.4	0.6	0
C22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0	-1	0.6	0	0
C23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2	0	0.6	0
C24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0
C25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
C26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0
C27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0.6
C28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 2: Adjacency matrix

DISCUSSION OF FINDINGS

There are a variety of methods for exploring cognitive maps. CMs are usually analysed in terms of their content and complexity. As CMs can be complex, graph theory indices provide a way to analyse their structures (Eden *et al*. 1992). In the CM of the case study, there are 28 concepts (Table 2) and 46 links. The complexity value as a network is 1.6, which is the ratio of links to concepts. As this number gets higher, the complexity of the map tends to increase. The most important factors as defined by the interviewee within the CM can be identified by calculating centrality values of the concepts. Centrality of a variable is the summation of its indegree and outdegree values (Ozesmi and Ozesmi 2003). The indegree value reveals the extent to which a concept is influenced by other concepts (column sum of the absolute values of a variable in the adjacency matrix) whereas outdegree value shows the cumulative strength of variables exiting the variable (row sum of the absolute values of a variable in the adjacency matrix). Transmitter variables have a positive outdegree and zero indegree whereas receiver variables have a zero outdegree and a positive indegree. Ordinary variables have both positive outdegree and indegree values (Eden *et al*. 1992). In the case study, the variables that have the highest outdegree values are "increase in cost", "delay" and "engineer" meaning that those variables significantly affect other variables. "Change in scope", "increase in the amount of work" and "delay" have the highest indegree value implying that these variables are significantly affected from others. It is understood from the CM that, the project success is significantly affected from risk events (such as economic risk, earthquake etc.) but the effects of these risks are first reflected to variables such as "productivity" and "delay". As well as the risk factors, there are certain variables like "wrong decisions" and "contingency in the bid price" that influence the consequence variables together with the risk factors. Majority of the 10 transmitter variables are risk factors (such as economic crises, earthquake etc.) and given conditions (poor geotechnical conditions, wrong selection of the construction method). The 13 ordinary variables (such as productivity) carry the impact of risks and given conditions to the forthcoming variables (such as delay). The centrality values of variables "design changes", "change in scope" and "increase in costs" are the highest among all concepts implying that they influence and influenced by many factors. It is clear that rather than listing a couple of reasons of success/failure, drawing a CM that explains the chain reactions between risk events, conditions, consequences and project success criteria is a better way of presenting the lessons learnt in a project. Particularly in this project, the project success seems to be negatively affected from the poor reputation of the company which is developed as a result of significant delays and poor profitability due to increase in the amount of works as a result of change orders by the client and scope changes due to unanticipated events like earthquake and flood. However, wrong decisions about project management and conflict between partners also significantly affected the project success and company may learn from these mistakes. Risk adjusted bid prices influences profitability in a positive way meaning that the company was successful in choosing the contingency percentage in this project, which is also a valuable piece of information for the forthcoming projects.

CONCLUSIONS

Although risk checklists are widely used in construction projects, their reliability is questionable as many risk factors are interrelated and there are some influencing factors that should be considered during risk assessment. Cognitive mapping is proposed as an alternative method in which the complex relations between risks and other factors may be effectively modelled. CMs may be used for risk identification at the start of a project so that the risk information can be communicated effectively and risk evaluation during post-project appraisal so as to facilitate organizational learning. In addition, CMs of different project participants may be drawn and compared to reveal potential areas of similarity and/or conflict. The case study findings demonstrate that lessons learnt in a project can be diagrammatically represented and may form an appropriate platform for discussing the sources and impacts of risks together with influencing factors. The CM can be interpreted using indices, which may provide summary information about a complex situation. Major advantages of using cognitive mapping are identified by the interviewee as visualization of the project environment, particularly chains of events that lead to success/failure and documentation of lessons learnt. The major drawback as specified by the interviewer is the complexity of the diagram. The size of the map should be tried to be minimized so that it may be easy to analyse and comprehend.

Finally, CMs are criticized as they may reflect the biases and misconceptions of participants. Actually, it may turn out to be an advantage if the aim is to reveal the similarities and dissimilarities between the mental models of participants. Although CMs may not be directly used as objective tools for risk quantification, they may provide valuable information about a network of variables and concepts within a project setting.

REFERENCES

Al-Shehab, A, Hughes, B and Winstanley, G (2004) Using causal mapping methods to identify and analyse risk in information system projects as a post-evaluation process. *In: 11th European Conference on Information Technology Evaluation Proceedings of ECITE 2004*, Amsterdam.

Ashley, D B and Bonner, J J (1987) Political risk in international construction. *ASCE Journal of Construction Engineering and Management*, September, 447–67.

Axelrod, R (1976) *Structure of Decision: The cognitive maps of political elites*. Princeton, NJ: Princeton University Press.

Carlsson, C and Fuller, R (1996) Adaptive fuzzy cognitive maps for hyperknowledge representation in strategy formation process. *In: Proceedings of International Panel Conference on Soft and Intelligent Computing*, Technical University of Budapest, 43–50.

Chen, J L and Stanney, K M (1999) A theoretical model of way finding in virtual environments: proposed strategies for navigational aiding. *Teleoperators and Virtual Environments*, **8(**6), 671–85.

Clarke, I and Mackaness, W (2001) Management intuition; an interpretative account of structure and content of decision schemas using cognitive maps. *Journal of Management Studies*, **38**(2), 147–72.

Dikmen, I, Birgonul, M T and Arikan, A E (2004) A critical review of risk management support tools. In: Proceedings of ARCOM 2004, 1–3 September 2004, Heriot Watt University, 2, 1145–54.

Dikmen, I, Birgonul, M T and Han, S. (2007) Using fuzzy risk assessment to rate cost overrun risk in international construction projects. *International Journal of Project Management* (article in press).

Eden, C (1992) Strategy development as a social process. *Journal of Management Studies*, **29**, 799–811.

Eden, C (2004) Analyzing cognitive maps to help structure issues or problems. *European Journal of Operational Research*, **159**, 673–86.

Eden, C, Ackermann, F and Cropper, S (1992) The analysis of cause maps. *Journal of Management Studies*, **29**, 309–24.

Jaafari, A (2001) Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management*, **19**, 89–101.

Kosko, B (1986) Fuzzy cognitive maps. *International Journal of Man-Machine Studies*, **24**, 65–75.

Kwahk, K Y and Kim, Y G (1999) Supporting business process redesign using cognitive maps. *Decision Support Systems*, **25**, 155–78.

Langfield-Smith, K M and Wirth, A (1992) Measuring differences between cognitive maps. *Journal of the Operational Research Society*, **43**, 1135–50.

Lee, K C and Lee, S (2003) A cognitive map simulation approach to adjusting the design factors of the electronic commerce web sites. *Expert Systems with Applications*, **24**(1), 1–11.

Noh, J B, Lee, K C, Kim, J K, Lee, J K and Kim, S H (2000) A case-based reasoning approach to cognitive map-driven tacit knowledge management. *Expert Systems with Applications*, **19**(4), 249–59.

Ozesmi, U and Ozesmi, S L (2003) A participatory approach to ecosystem conservation: fuzzy cognitive maps and stakeholder group analysis in Uluabat lake. *Environmental Management*, **31**(4), 518–31.

Poh, Y P and Tah J H M (2006) Integrated duration–cost influence network for modelling risk impacts on construction tasks. *Construction Management and Economics*, **24**, 861–8.

Rodriguez-Repiso, L, Setchi, R, and Salmeron J L (2007) Modelling IT projects success with fuzzy cognitive maps. *Expert Systems with Applications*, **32**(2), 543–59.

Smith, N, Ackermann, F, and Eden, C (1995) Cognitive mapping – a 'hot button' approach to IT strategy development. Management Science Working Paper, 95/15, University of Strathclyde.

PREDICTING THE OPERATION AND MAINTENANCE COSTS OF APARTMENT BUILDINGS AT PRELIMINARY DESIGN STAGE: COMPARING STATISTICAL REGRESSION AND ARTIFICIAL NEURAL NETWORK METHODS

Kung-Jen Tu,[1] Yuan-Wei Huang,[1] Chao-Ling Lu[2] and Kuo-Hui Chu[3]

[1]*Department of Architecture, National Taiwan University of Science and Technology, 43 Keelung Rd., Section 4, Taipei City, Taiwan 106*
[2]*Department of Architecture Technique, Taipei Municipal Da-an Vocational High School, 52 Fusing South Rd., Section 2, Taipei City, Taiwan 106*
[3]*Land Development, Sotai Real Estate, 10F, 501, Tiding Blvd., Section 2, Taipei City, Taiwan 114*

In Taiwan, public facilities of many apartment buildings often became obsolete because their operation and maintenance (O&M) costs were too high for residents to afford. Since the design decisions at preliminary design stage would greatly affect a building's O&M cost during occupancy stage, the possibility of public facility obsolescence can be greatly reduced if accurate O&M costs prediction models to be used at preliminary design stage are developed. The objectives of this research are to employ statistical regression and artificial neural network (ANN) methods to develop two O&M prediction cost models used at preliminary design stage of apartment building projects, as well as to compare the predictive capability and accuracy of both models. Six design attributes were identified as critical factors to be considered at preliminary design stage as well as the inputs of both cost prediction models: building age, number of apartment units, number of floors, average sale price, total floor area, and public facility floor area. Sixty-five apartment buildings in Taipei City and Taipei County were identified as the subjects of this research, and data related to the six design attributes and O&M cost were collected. Data of 55 apartment buildings were used to develop the regression model and ANN model, and those of the remaining 10 apartment buildings were used to compare the performance of both models. The study revealed that the ANN model is a more accurate and stable cost prediction model (with a maximum error around 15%) as compared with the regression model.

Keywords: artificial neural network, cost modelling, maintenance, regression analysis.

INTRODUCTION

Background

In the development and design of apartment buildings in Taiwan, there has developed a trend that higher percentages of floor areas, as high as 35% of total floor areas (Chen and Chen 1999), are allocated for public facilities, such as lobby, service core, equipment rooms, guardrooms, central monitoring rooms, conference rooms, audio-video rooms, swimming pools, gyms, libraries, and so on, to fully meet residents' functional and recreational needs in their daily lives. However, a domestic study and

[1] kjtu@mail.ntust.edu.tw

investigation revealed that many public facilities of such apartment buildings have become obsolete because the operation and maintenance costs of these apartment buildings were too high for their residents to afford (Chen and Chen 1999).

Since high percentages of building operation costs were determined by programming decisions and building specifications in early design phases (Bogenstätter 2000), it is imperative to develop accurate O&M cost prediction methods that can be used at preliminary design stage. With accurate O&M cost prediction methods, housing developers and architects can make better development and design decisions about the types and scales of public facilities of apartment buildings at early design stage by being informed of their predicted O&M costs. With the mechanism to ensure that the O&M costs to be shared by the residents are affordable, the possibility of public facilities obsolescence in apartment buildings can thus be greatly reduced.

Literature review: existing prediction models in the building construction field

A review of existing literature was conducted to realize the status of research works related to the prediction of operation and maintenance costs or life cycle costs in the building construction field. It was found that there has been a lack of development of prediction models to estimate buildings' O&M costs at preliminary design stage.

However, some research efforts dealing with other aspects of O&M costs or life cycle costs have been observed. For examples, Kirkham *et al*. (2002) demonstrated a methodology for modelling accurately the underlying 'probability distributions' of facility management costs in acute care hospital buildings in England and Wales, distributions that can be used in subsequent whole life cycle costing analysis. By compiling historical data of life cycle costs of hundreds of buildings, Bogenstätter (2000) calculated the 'characteristic values' of life cycle costs (average costs per square metre of gross floor area and variations represented in percentages) for each type of building, with the intention to provide architects and engineers with historical cost data and distributions information in early design stage so that the life cycle costs of the development building projects can be optimized strategically. Besides, Minami (2004) conducted a survey on a large number of post office buildings in Japan to investigate the patterns and trends of their annual repair and improvement work costs. None of these research efforts came up with prediction models that can be used in early design stage to predict the future O&M costs of buildings.

In addition, this research has uncovered a number of prediction methods that have been used for other purposes in the building construction field. For example, regression analysis was used to estimate the life cycle maintenance costs of hydraulic construction excavators over their useful lives (Edwards *et al.* 2000; Edwards and Holt 2001). In fact, existing literature in other research fields abounds with examples of the application of statistical regression methods to cost modelling. It is logical to consider statistical regression analysis as a potential candidate to model and predict O&M costs of apartment buildings at preliminary design stage.

It's also found that artificial neural network (ANN) has been used to predict building construction costs or certain performance aspects in the building construction field. For examples, ANN was used in early design phase to estimate the square metre cost of RC structural systems of residential buildings in Turkey (Günaydın and Doğan 2004). ANN cost model was developed to predict the total construction costs of building projects (Emsley *et al*. 2002; Kim *et al*. 2004). To ensure design-build project success, key variables that affect project performance were identified, and ANN technique was employed to predict the performance (cost, time, quality and client satisfaction) of design-build projects in Singapore (Ling and Liu 2004).

Artificial neural network (ANN) is a mathematical informational processing model that can learn from past examples or training data (Taylor 1996). Not only has it been used to perform classification, clustering and control tasks, but it has also been successfully applied to function approximation (Hill *et al*. 1994). Several distinguishing features of ANN make it valuable and attractive for a forecasting task: ANN is a data-driven self-adaptive method with the ability to learn from past experience; it can generalize what's learned from data and infer the unseen part of a population correctly; it can approximate any continuous function to any desired accuracy; and it is capable of performing non-linear modelling without *a priori* knowledge about the relationships between input and output variables (Zhang *et al*. 1998). ANN appears to be a more general and flexible modelling tool for forecasting, and has been applied to forecast non-linear time series, such as stock prices (Kohzadi *et al*. 1996), foreign exchange rate (Hann and Steurer 1996), electric load consumption (Srinivasan *et al*. 1994), and so on, with high accuracy.

Compared to the traditional model-based forecasting methods requiring assumptions about the underlying relationship between the input and output variables, ANN appears to be a promising method of O&M cost prediction for apartment buildings in early design stage, and a good candidate as an alternative modelling method to the classical regression analysis.

Research objectives

This research intends to develop accurate O&M cost prediction methods that can be used at the preliminary design stage of apartment building projects. The regression analysis and ANN were chosen by this research to establish two O&M cost prediction models for apartment buildings. To be more specific, the objectives of this research are: (1) to develop the regression model for O&M cost prediction; (2) to establish the artificial neural network (ANN) model for O&M cost prediction; and (3) to compare the predictive capability and accuracy of both models.

THEORETICAL FRAMEWORK

Key elements of O&M cost prediction models

The major role of the proposed O&M cost prediction models is to allow housing developers and architects to predict and estimate the future O&M costs of their proposed design schemes at preliminary design stages of apartment building projects. Through numerous rounds of O&M cost evaluations on proposed schemes at preliminary design stage, optimal design decisions regarding apartment buildings and public facilities can be made, future O&M costs to be shared by residents can be ensured to be affordable, and the possibility of public facility obsolescence can be minimized.

The proposed regression and ANN models will take building design attributes at preliminary stage as inputs to predict the building O&M cost as the output. To meet the specific needs of developers and designers in making design decisions at the preliminary design stage, it's argued that the proposed O&M cost prediction models should consist of the following four key elements:

1. *Meaningful building design attributes as the inputs to the proposed models*: the design attributes identified must be those typically known at preliminary design stage, and must be meaningful to housing developers and architects.
2. *Useful O&M cost factors as the outputs of the proposed models*: the O&M cost factors should be in a form useful to housing developers and architects in different contexts, and should provide the most flexibility so that different schemes can be applied subsequently.
3. *A representative sampling dataset based on previously analysed apartment building subjects*: the sampling data must represent a wide range of apartment buildings and contain many complete input samples of building design attribute data and corresponding outputs of O&M cost factors.
4. *Accurate and responsive O&M cost prediction models*: the structure of the proposed O&M cost models must be validated to ensure predictive accuracy. The proposed models should be easy to use and be responsive in providing O&M cost prediction results so that housing developers and architects can make fast comparisons of cost performance of different design schemes.

Operation and maintenance cost factors

In Taiwan, the costs to operate and maintain the public areas and facilities in apartment buildings generally consist of four parts: service cost (administration, security, cleaning); energy consumption cost (water, electricity); maintenance cost (mechanical equipment and landscape); as well as refurbishment and repair cost (interior remodel, structure and mechanical equipment repair). The O&M costs are typically shared by residents, in proportion to the area of their apartment units.

The first issue is to identify feasible O&M cost factors as the outputs of the regression and ANN models. After considering the requirements for O&M cost factors stated above, the following cost factor was identified as the output of the proposed model:

- Average monthly O&M cost: the annual total building O&M cost of an apartment building divided by 12 (NTD/month).

Apartment building design attributes

Building design attributes as the inputs to the proposed models need to be logically and statistically linked to the O&M cost, and to be readily available at preliminary stage. The design attributes must be able to discriminate between different concepts and be compact so that the demands on learning O&M cost model are reasonable. Finally, they must be easily understood by housing developers and architects. With these goals in mind, the existing literature was reviewed and experts were consulted to identify critical building design attributes.

Chen and Chen (1999) found that older apartment buildings in Taiwan incurred higher refurbishment costs, and larger and taller buildings incurred higher O&M costs. These findings suggest that building age, the number of apartment units or total floor area, and the number of floors of an apartment building may be related to its O&M cost.

Six experts experienced in developing, designing and managing apartment buildings were interviewed, and an open-ended question, i.e. 'what design decisions at building preliminary design phase may affect its future O&M cost?', was asked. Content analysis on experts' responses was then conducted. As a result, additional factors that may affect a building's O&M costs, such as the grade of apartment buildings, and the size or the diversity of public facilities, were identified.

As a result, the following six building design attributes were identified and their effects on O&M cost are speculated:

1. *Building age (year)*: the number of years between the year the building was registered and 2005. It is believed that the older the building, the more facility problems it has, and the higher its O&M cost.
2. *Number of apartment units (unit)*: the total number of apartment units in the apartment buildings with the same building registration number. It is speculated that the more apartment units, the greater number of residents, the heavier the public facilities consumed, and the higher its O&M cost.
3. *Number of floors (floor)*: total number of floors (including basement floors) of the apartment buildings with the same building registration number. It is supposed that the taller the building, the more complicated and sophisticated mechanical systems it is equipped with, and the higher its O&M cost.
4. *Average sale price (NTD/ping[1])*: the average price of apartment units purchased by residents at the time of building registration. It is suggested that the higher the sale price, the higher is the quality of public facilities demanded and provided, and the higher the cost required to operate and maintain the building.
5. *Total floor area (ping)*: total floor area (including basement floors) of the apartment buildings with the same building registration number. It is conjectured that the larger the total floor area, the larger the floor area of public facilities to be maintained, and the higher the building O&M cost.
6. *Public floor area (ping)*: total floor area designated as public facilities or uses in the apartment buildings with the same building registration number. It is logical to assume that the greater the public floor area in an apartment building, the more O&M work needs to be done, and the higher the building O&M cost.

RESEARCH METHODS

Data collection

This research randomly selected 200 apartment building communities from a population of 6682 communities whose commissions have officially been registered in Taipei City and Taipei County. After contacting the commissions of the 200 communities, 65 of them agreed to participate in this research and were identified as the subjects of this study. All 65 apartment buildings are private residential communities consisting of individually owned condominiums, most of which are occupied by owners and a small portion by tenants. Data related to the six design variables and the O&M cost of each apartment building community were collected by interviewing the members of its commission between August and November 2005. Structured questions regarding the annual total O&M cost and the six design attributes, as well as open-ended questions regarding the operation and management system (how the commission is organized, how the building is operated and managed, how the O&M cost is shared by residents), of apartment buildings were asked during the interviews. Fifty-five out of the 65 apartment building communities were randomly selected as ‘modelling subjects’ to establish both cost prediction models. The remaining 10 apartment building communities were treated as the ‘test subjects’ to examine the predictive capability and accuracy of both models. The distributions of dependent and independent variables of the 55 ‘modelling subjects’ are shown in Table 1.

Table 1: The distributions of dependent and independent variables of 55 modelling subjects

	Independent variables						Dependent variable
	Building age (year)	**Apt. unit number** (unit)	**Floor number** (floor)	**Average sale price** (NTD/ping)	**Total floor area** (ping)	**Public floor area** (ping)	**Actual O&M cost** (NTD/mon)
Minimum	1	20	6	82000	1357	184	100000
Maximum	18	800	33	555000	34431	7155	1672473
Average	5	187	17	210763	8023	2112	450967

Table 2: The correlation coefficients among the six design variables of apartment buildings

	Building age (X_1)	**Apt. unit number** (X_2)	**Floor number** (X_3)	**Average sale price** (X_4)	**Total floor area** (X_5)	**Public floor area** (X_6)
Building age (X_1)	1					
Apt. unit number (X_2)	–0.04	1				
Floor number (X_3)	–0.45	0.49	1			
Average sale price (X_4)	–0.11	–0.38	0.04	1		
Total floor area (X_5)	–0.02	**0.84**	0.55	–0.14	1	
Public floor area (X_6)	–0.14	**0.77**	0.58	–0.08	**0.93**	1

The regression model

A stepwise regression procedure on the sampling data was used to identify significant independent variables for predicting the O&M costs of apartment buildings. The preliminary regression model of O&M cost of apartment buildings is given in Equation 1:

$$Y = \beta_0 + \beta_1 \times X_1 + \beta_2 \times X_2 + \beta_3 \times X_3 + \beta_4 \times X_4 + \beta_5 \times X_5 + \beta_6 \times X_6 + \varepsilon \quad (1)$$

where Y is the predicted O&M cost (NTD/month); X_1 is the age of the apartment building (year); X_2 is the number of apartment units in the building (unit); X_3 is total number of floors (floor); X_4 is the average sale price (NTD/ping); X_5 is the total floor area (ping); X_6 is the floor area of public used area (ping); and the coefficients β_i (i = 1, 2, …, 6) represent the corresponding constants.

The SPSS statistical software system was used for establishing the regression model. To avoid the problem of ‘multicollinearity’ in multiple regression analysis, the correlations among the six design variables were first examined. As shown in Table 2, X_2 (number of apartment units), X_5 (total floor area) and X_6 (public floor area) are highly correlated (coefficients r = 0.84, 0.77, 0.93). Since the information of ‘total floor area’ is usually available at preliminary design stage of an apartment building, and it is a more objective measure of the ‘scale’ of apartment building projects, X_5 was kept and X_2 and X_6 were eliminated from the regression model. A forward stepwise regression procedure was employed and multiple regression analysis was performed on the remaining four independent variables.

The results of the regression analysis indicated that approximately 76% (adjusted-R^2) of the variation in the dependent variable Y (O&M cost) can be explained by two significant independent variables X_4 (average market unit price, $\beta_4 = 0.9$, $p < 0.01$) and X_5 (total floor area, $\beta_5 = 52.7$, $p < 0.001$); and the independent variables of X_1 (building age) and X_2 (household number) appeared to be insignificant (Table 3). The final regression model was reformulated by eliminating the insignificant independent variables as Equation 2:

$$Y = -143614.0 + 0.9 \times X_4 + 52.7 \times X_5 \quad (2)$$

With the established regression model, one can predict the O&M cost of an apartment building at preliminary design stage. By providing the data of two design attributes, average sale price (X_4) and total floor area (X_5), of an apartment building into Equation 2, its O&M cost can be calculated and predicted.

Table 3: Results of multiple regression analysis of the O&M cost prediction model.

	Regression model Y: O&M cost (NTD / month) (N = 55)		
	β	**SE**	**T-value**
Building age (X_1)	–2970.6	7976.6	–0.37
Floor number (X_3)	–609.9	7127.8	–0.09
Average sale price (X_4)	0.9**	0.3	3.07
Total floor area (X_5)	52.7***	5.7	9.30
Intercept (β_0)	–143614.0*	140773.6	–1.02
R-square (R^2)		0.76	

Notes: *p < 0.05; **p < 0.01; ***p < 0.001.

The artificial neural network (ANN) model

Data of the six design attributes (inputs) and the O&M costs (output) of 55 modelling subjects were used as the training sample, and back propagation learning algorithm was used along with the software Neuralyst v 1.4 to establish the ANN O&M cost prediction model. It's decided that multilayer perceptrons (MLP) network architecture was used, and that the six design attributes defined as the six input neurons and the O&M cost as the output neuron of the network architecture. The following steps were taken to establish the ANN model:

1. *Data normalization*: data of six input variables of 55 subjects were first normalized by employing the 'along channel normalization' method, and then loaded into the software along with the O&M cost data (output variable).
2. *Parameter setting*: a set of parameter values, such as the number of hidden layers and the number of neurons in hidden layers, learning rate and momentum, were assigned in the software.
3. *Network training*: for the set of parameter values assigned, the back propagation algorithm was used for neural network training, in which weights of a network are iteratively modified to minimize the overall mean or total squared error between the desired and actual output values for all output nodes over all input patterns. As a result, a 'root mean squared error (RMSE)', indicating the forecasting error of the set of parameter values was generated.
4. *Trial and error*: by repeatedly assigning different sets of values of hidden layer number (0, 1, 2), neuron number in hidden layers (4, 5), learning rate and

momentum (both between 0 and 1), as well as performing neural network training, a best combination of learning rates, momentum, number of hidden layers, number of neurons in hidden layers, learning rules and transfer functions that resulted in a minimal RMSE was identified.

As a result, the ANN model with an architecture consisting of an input layer of six input neurons, a hidden layer of five neurons, and an output layer of one neuron was established (Figure 1). The most popular learning rules, generalized delta rules and a sigmoid transfer function were used for the output neuron, the learning rate was 1.0, the momentum was 0.85, the number of iteration was 2981, and the root mean squared error (RMSE) was 0.031.

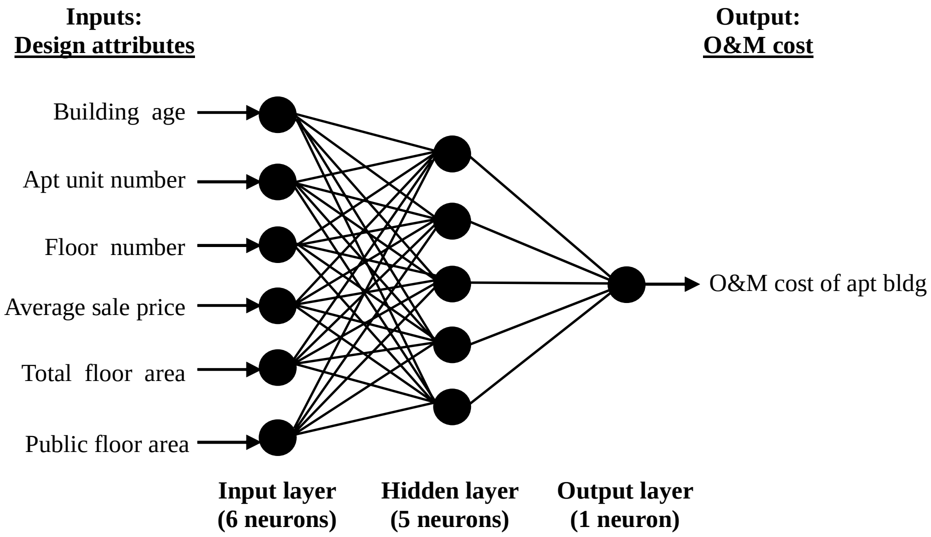


Figure 1: The neural network architecture for predicting O&M costs of apartment buildings

With the established ANN model, one can predict the O&M cost of an apartment building at preliminary design stage. By providing the data of six design attributes of the apartment building as the inputs to the ANN model, its O&M cost can be generated by the ANN model as the output.

Table 4: Data of the six design attributes and the O&M costs of the ten test subjects.

	Independent variables						Dependent variable
Test subjects	**Building age** (year)	**Apt. unit number** (unit)	**Floor number** (floors)	**Average sale price** (NTD/ping)	**Total floor area** (ping)	**Public floor area** (ping)	**Actual O&M cost** (NTD/month)
TS-1	6	70	9	100000	2730	409	68445
TS-2	10	9	6	97000	4765	434	116311
TS-3	8	127	16	110000	3714	290	210217
TS-4	10	92	19	320000	4845	1507	356951
TS-5	8	300	15	108000	7137	2617	367889
TS-6	2	93	15	215000	2288	899	413035
TS-7	11	178	14	125000	6524	972	478218
TS-8	10	250	17	145000	15845	305	666939
TS-9	10	273	15	120000	9825	1552	678900
TS-10	6	400	20	125000	17714	893	1120000

RESULTS AND DISCUSSION

Predictive capability and accuracy of prediction models

The predictive capability and accuracy of both models were examined by comparing the actual O&M costs of 10 apartment building test subjects with the O&M costs predicted by the proposed regression model and ANN model. Data of the six design attributes and the actual O&M costs of the 10 test subjects are shown in Table 4.

To obtain the predicted O&M costs of the 10 test subjects from the 'regression model', the data of average market sale price (X_4) and total floor area (X_5) were fed into Equation 2 and their O&M costs calculated. To obtain the predicted O&M costs of the 10 test subjects from the 'ANN model', the data of six design attributes were provided as the inputs to the ANN model, and their O&M costs generated as the outputs. The O&M costs predicted by both models as well as their deviations from the actual O&M costs (percentage of error) are shown in Table 5 and Figure 2.

Table 5: The actual O&M costs and those predicted by the regression and ANN models

Test subjects	**Actual O&M cost** (NTD/month)	**Regression model**		**ANN model**	
		Predicted O&M cost (NTD/month)	**% error**	**Predicted O&M cost** (NTD/month)	**% error**
TS-1	68445	89519	30.8 %	65756	–3.9 %
TS-2	116311	194112	66.9 %	132433	13.9 %
TS-3	210217	150305	–28.5 %	192634	–8.4 %
TS-4	356951	397422	11.3 %	353846	–0.9 %
TS-5	367889	328912	–10.6 %	368514	0.2 %
TS-6	413035	168911	–59.1 %	360614	–12.7 %
TS-7	478218	311778	–34.8 %	410952	–14.1 %
TS-8	666939	820876	23.1 %	678523	1.7 %
TS-9	678900	481286	–29.1 %	785163	15.7 %
TS-10	1120000	901517	–19.5 %	1108402	–1.0 %
Ave. abs. error			31.4 %		7.3 %
Max. abs. error			66.9 %		15.7 %

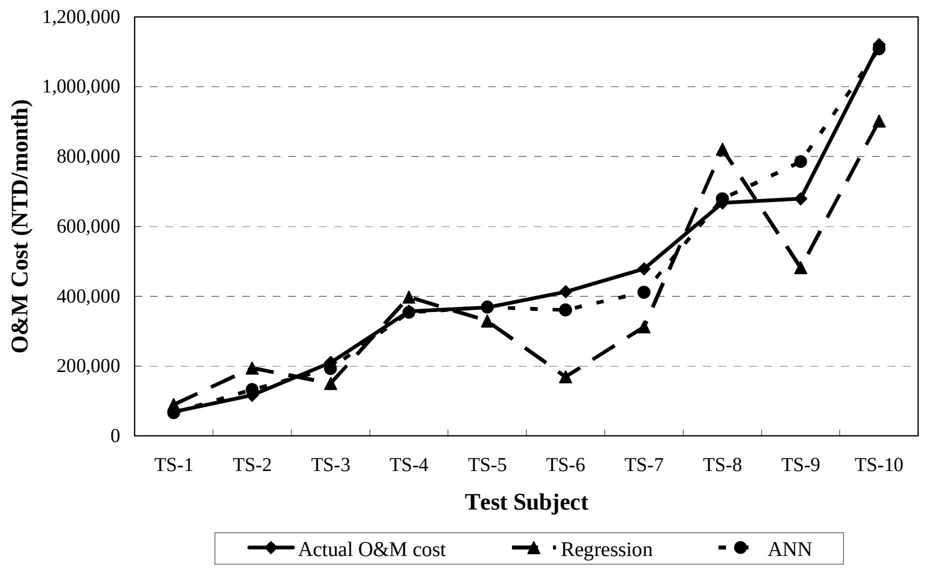


Figure 2: Comparison of actual O&M costs and those predicted by regression & ANN models

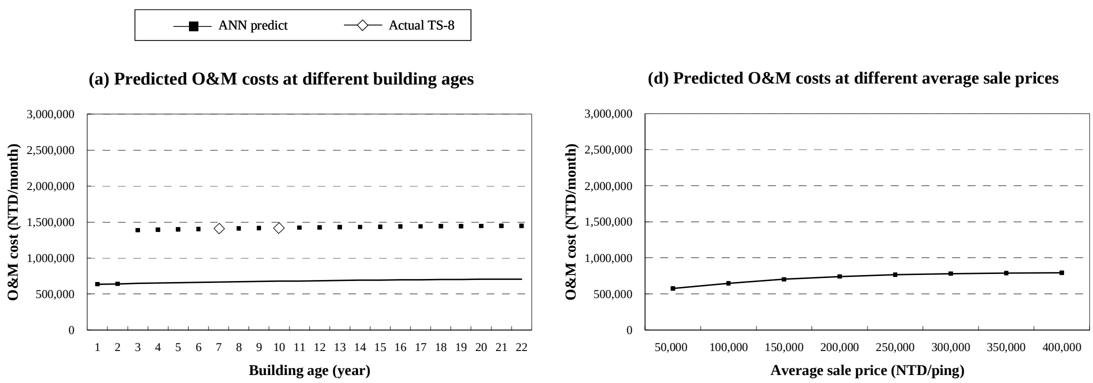
In Table 5, it can be observed that the ANN model generally outperformed the regression model in predicting O&M costs of apartment buildings. The O&M costs predicted by the ANN model have lower average absolute errors than those predicted by the regression model (7.3% vs. 31.4%). The absolute errors of the costs results predicted by the ANN model ranged from 0.2 to 15.7%, with an average absolute error of 7.3%, whereas the absolute errors of the O&M costs predicted by the regression model ranged from 10.6 to 66.9%, with an average absolute error of 31.4%. This means the deviations of the predicted costs by the ANN model from the actual costs are smaller, and indicates that the ANN model generates more accurate cost results.

Besides, the ANN model also generated cost results with smaller maximum absolute error than the regression model (15.7% vs. 66.9%). This means the degree of possible errors of the ANN model is smaller than that of the regression model, and indicates that the ANN model generates more stable cost results.

In conclusion, the ANN model is a more accurate and stable cost prediction model (with a maximum error around 15%) as compared with the regression model. The O&M cost results predicted by the ANN model appear to be satisfactory.

The ANN model: predicting trends of building O&M costs

To demonstrate how each of the six design attributes affects building O&M cost in the ANN model, as well as to test the ANN model's estimation ability to generalize and predict the trends of O&M costs correctly for a given design attribute, TS-8 was randomly selected from the 10 test subjects, whose data of design attributes and O&M cost were used for further analyses. To examine the effects of a design attribute, say 'building age', on building O&M costs, the remaining five design attributes of TS-8 were held constant in the ANN model, and different 'building ages' were input into the ANN model to obtain corresponding predicted O&M costs. The trend of predicted O&M costs at different building ages and the actual O&M cost of TS-8 (666 939 NTD) at its building age (10 years old) were plotted and compared. The trend results of the predicted O&M costs related to the six design attributes were analysed similarly and illustrated in Figure 3 (a–f).



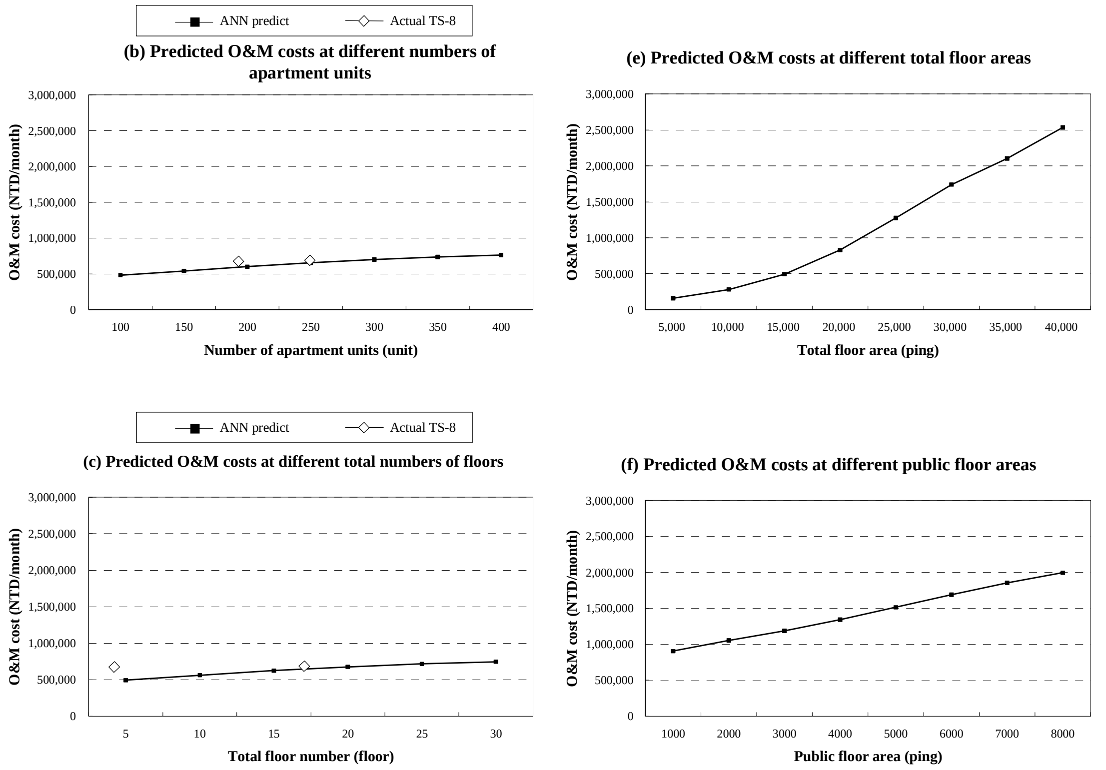


Figure 3: The trend results of the predicted O&M costs related to each of the six design attributes in the ANN model vs. the actual O&M cost of TS-8

The effect of each design attribute on building O&M cost in the ANN model is revealed by the slope of its trend line. As indicated in Figure 3, for a particular apartment building with design attributes similar to TS-8, it's predicted by the ANN model that its O&M cost is primarily affected by its 'total floor area' and 'public floor area' (steeper slopes), less affected by its 'apartment unit number', 'total floor number' and 'average sale price', and does not change much at different stages of its building life. The trend results of O&M costs of apartment buildings with different characteristics and design attributes can be analysed and examined similarly.

The estimation ability of the ANN model to generalize and predict the trend of O&M cost correctly is indicated by the relationship between the actual O&M cost of TS-8 and the predicted trend line in each of the six plots in Figure 3. Generally speaking, the actual O&M cost of TS-8 is relatively close to the predicted trend line in each plot, suggesting that the ANN model developed is effective in generalizing and predicting the trends of the O&M costs of apartment buildings.

CONCLUSIONS

This research was motivated by the urgent need of an analytic method to predict the life cycle O&M cost of an apartment building at its preliminary design stage. Typical operation and maintenance tasks carried out in existing apartment buildings in Taiwan and associated costs were examined. Six design attributes (building age, number of apartment units, number of floors, average sale price, total floor area, public floor area) of apartment building projects which could affect their life cycle O&M costs were then identified. The regression model and the artificial neural network (ANN) model were developed to predict O&M costs of apartment buildings at their preliminary design stages. The six design attributes were designated as the inputs or independent variables of both models, and the O&M cost as the output or dependent variable of both cost prediction models. Data related to the six design attributes (inputs) and the O&M costs (output) of apartment building test subjects were used to examine and compare the predictive capability and accuracy of both models.

The ANN model appears to be a more accurate and stable O&M cost prediction model as compared with the regression model. In particular, the ANN model generates O&M cost prediction results with a lower average absolute error and a lower maximum absolute error than the regression model. The O&M cost results predicted by the ANN model appear to be satisfactory (with a maximum error around 15%).

Although producing acceptable results, this research is only in its preliminary stage in pursuit of methods to predict the O&M costs of apartment buildings at the preliminary design stage. To ensure that the ANN model provides the developers and architects of apartment building projects with reliable prediction results, the ANN model requires further testing and validation. A number of research tasks to be fulfilled are identified.

In the regression model, it seems to be a problem when trying to establish the relationship between the ages, sale prices, O&M costs of existing buildings, and to predict future O&M costs (at different ages) of today's building based on its current 'sale price' and the relationship found from yesterday's buildings, because it assumes a relationship between input and output variables. As for the ANN model, it is not a problem, since it only tries to learn from historical data and experience, and does not intend to derive a theory about the underlying law governing the system. Nonetheless, the applicability of the six design attributes of the ANN model will be further examined and validated.

Other potential design attributes that may affect building O&M costs will also be included and tested. More apartment buildings test subjects, especially those with great variances in various design attributes (inputs), will be used to test the accuracy and stability of the ANN model in cost predictions of 'cross-sectional' subjects. Besides, the ANN model will be tested against subjects with year-by-year O&M cost data to examine its accuracy and stability in cost predictions of 'longitudinal' subjects.

ACKNOWLEDGEMENT

The authors would like to thank the National Science Council of the Executive Yuan of Taiwan for sponsoring this research work (Project No. NSC 91-2211-E-011-051).

NOTES

1. NTD = New Taiwan Dollar, 1 GBP ≈ 64 NTD; 'Ping' is a conventional measure of area often used in Taiwan, 1 ping ≈ 1.8m × 1.8m.

REFERENCES

Bogenstätter, U (2000) Prediction and optimization of life-cycle costs in early design. *Building Research & Information*, **28**(5/6), 376–86.

Chen, J H and Chen, G L (1999) *The investigation of the appropriateness and management of public facilities in apartment buildings*, Research Project Report, the Architectural and Building Research Institute, the Ministry of Interior.

Edwards, D J and Holt, G D (2001) Predicting construction plant maintenance expenditure. *Building Research & Information*, **29**(6), 417–27.

Edwards, D J, Holt, G D and Harris, F C (2000) Estimating life cycle plant maintenance costs. *Construction Management and Economics*, **18**(4), 427–35.

Emsley, M W, Lowe, D J, Duff, A R, Harding, A and Hickson, A (2002) Data modelling and the application of a neural network approach to the prediction of total construction costs. *Construction Management and Economics*, **20**(6), 465–72.

Günaydın, H M and Doğan, S Z (2004) A neural network approach for early cost estimation of structural systems of buildings. *International Journal of Project Management*, **22**(7), 595–602.

Hann, T H and Steurer, H (1996) Much ado about nothing? Exchange rate forecasting: neural networks vs. linear models using monthly and weekly data. *Neurocomputing*, **10**(4), 323–39.

Hill, T, Marquez, L, O'Connor, M and Remus, W (1994) Artificial neural network models for forecasting and decision making. *International Journal of Forecasting*, **10**(1), 5–15.

Kim, G H, An, S H and Kang, K I (2004) Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning. *Building and Environment*, **39**(10), 1235–42.

Kirkham, R J, Boussabaine, A H and Awwad, B H (2002) Probability distributions of facilities management costs for whole life cycle costing in acute care NHS hospital buildings. *Construction Management and Economics*, **20**(3), 251–61.

Kohzadi, N, Boyd, M S, Kermanshahi, B and Kaastra, I (1996) A comparison of artificial neural network and time series models for forecasting commodity prices. *Neurocomputing*, **10**(2), 169–81.

Ling, Y Y and Liu, M (2004) Using neural network to predict performance of design-build projects in Singapore. *Building and Environment*, **39**(10), 1263–74.

Minami, K (2004) Whole life appraisal of the repair and improvement work costs of Post Office buildings in Japan. *Construction Management and Economics*, **22**(3), 311–18.

Srinivasan, D, Liew, A C and Chang, C S (1994) A neural network short-term load forecastor. *Electric Power Systems Research*, **28**(3), 227–34.

Taylor, J G (1996) *Neural networks and their applications*. New York: John Wiley & Sons.

Zhang, G, Patuwo, B E and Hu, M Y (1998) Forecasting with artificial neural networks: the state of the art. *International Journal of Forecasting*, **14**(1), 35–62.

STRUCTURAL EQUATION MODEL OF SAFETY CULTURE AND WORKER BEHAVIOUR IN CONSTRUCTION

Andi Andi[1]

Department of Civil Engineering, Petra Christian University, Jalan Siwalankerto 121–131, Surabaya 60236, Indonesia

The organizational preconditions to accidents are perceived as increasingly important for construction safety management. Empirical examination of the influence of organizational safety culture, including management commitment, safety rules and procedures, communication, competence, work environment and worker's involvement, on workers' safety behaviour is an important step to understand this notion. Data were collected from three large construction projects using a questionnaire and a total of 207 valid questionnaires were returned and formed the basis for structural equation modelling and subsequent analyses. The analyses results indicate only four safety culture factors having significant influence on workers' behaviour. The research concludes that top management commitment is a pivotal driver of safety culture, and the workers' behaviour can be controlled using the combination of prescriptive and discretionary approaches.

Keywords: accident, questionnaire survey, safety culture, structural equation model, worker behaviour.

INTRODUCTION

Mohamed (2002) mentions that the construction industry has a poor safety record compared to other industries. There are many perceptions indicating that accidents in construction projects, which can range from minor injuries to loss of life, originate from workers' unsafe acts (Hinze 1997). In other words, unsafe acts (or sometimes called human errors) are the main causes of accidents. However, this perception is disputed by Reason (1990), who states that attempts to reduce accidents by focusing only on unsafe acts will not be able to tackle the underlying causes. Reason (2000) give the example of mosquitoes as unsafe acts. They can be swatted one by one, but they still keep coming. The best remedies are to create more effective defences and drain the swamps in which they breed. The swamps, in this case, are the ever-present latent factors lying beneath the organizational and managerial factors.

Recently, there has been a shift in managing safety from a measurement that considers just accident rates to a management that takes into account safety culture (Cooper 2000). This consideration is driven by awareness that the underlying causes of accidents originate from organizational and managerial factors (Reason 1995). Therefore, attempts to measure safety culture constitute a

[1] andi@peter.petra.ac.id

very important step in order to generate safe working conditions and in the end to reduce accident rates.

Empirical studies considering safety culture have been progressing in the manufacturing industry (Cheyne *et al*. 1998; Oliver *et al*. 2002), but are still very limited in construction. In his study, Mohamed (2002) found a significant influence of safety culture on construction worker behaviour. The study however was limited to the direct relationship between safety culture and worker behaviour, and did not examine the interaction between safety culture factors. Considering the limitation, this paper attempts to propose and examine a causal model representing direct and indirect relationships between safety culture factors and worker behaviour.

SAFETY CULTURE

Safety culture is a sub-component of corporate culture, which alludes to individual, job and organizational features that affect and influence health and safety (Cooper 2000). Uttal (1983) defines it as shared values and beliefs that interact with an organization's structure and control systems to produce behavioural norms (cited in Cooper 2000). Another definition by Turner (1992) is the set of people's shared beliefs, norms, attitudes and expectations shared collectively by members of a society, organization or group.

Defining and measuring safety culture are complex tasks when all of the above facets are considered. In this study safety culture is composed of six main factors, i.e. top management commitment, safety rules and procedures, communications, workers' competency, workers' involvement and work environment. The following sections briefly discuss these safety culture factors.

Top management commitment

According to Reason (1997) a safety programme should be initiated from the top management of an organization. The top management should formulate a policy indicating a commitment to safety. This step will lead other policy makers concerning safety. Without it, it is very difficult to achieve a successful safety programme (Cheyne *et al*. 1998; Mohamed 2002). Marsh *et al*. (1998) have shown that management commitment was the most significant measure to determine and influence safety performance in 26 building sites across the United Kingdom.

Safety rules and procedures

The presence of safety rules and procedures may minimize accidents caused by unsafe conditions because they give a clear picture of safety programme implementation in construction projects (Pipitsupaphol 2003). The problems often found are that the rules and procedures are difficult to understand and implement, inappropriate with the current conditions, and there is over-specification.

Communications

Communications-related problems have been repeatedly reported in the literature to be responsible for many human errors resulting in structural failures, design quality problems, building defects and design defects (Andi and Minato 2004). It is thus important, in order to support a site safety programme, to make available appropriate information lines from management to workers and vice versa. Information such as unsafe conditions and new rules and procedures are very important to support the safety programme.

Worker competence
Workers' adequate knowledge, skill and ability in their work, especially towards risks and dangers in their work, may minimize accidents. These competences can be enhanced through training and appropriate workers selection (Mohamed 2002).

Work environment
Workplace factors are situations and conditions within the place where the workers work, which directly lead workers, as individuals or as a team, to initiate unsafe behaviour. This may cover such internal conditions as motivation, boredom, and also external conditions as time pressure and blaming culture.

Worker involvement
Workers' involvement is very important in building workers' awareness towards safety programmes. The form of involvement can be workers' participation during development of the safety programme and accident or unsafe act investigation and reporting. It is hypothesized that a higher level of involvement will give more positive influence to the safety behaviour.

A PRIORI MODEL

Figure 1 shows an *a priori* model representing the influence of safety culture on worker safety behaviour. The proposed model included six cultural factors and one worker behaviour factor. Each factor was composed of several indicators, and in total 39 indicators were used to measure the seven factors. The model also described the direct and indirect effects of safety culture factors, which were determined by consulting previous related research (Cheyne *et al*. 1998; Oliver *et al*. 2003; Mohamed 2002). There were 21 paths considered in the model, where each indicated a one-way effect (influence) from one factor to other factor.

RESEARCH METHOD

Data for the research were gathered by distributing questionnaires to construction workers. The questionnaire consisted of three parts, where the first part covered general information about the respondents and the project. The second part included the six factors of safety culture. Here the respondents were given a number of statements indicating the condition of each factor, and then asked to rate their agreement using a six-point rating scale from 1 (strongly disagree) to 6 (strongly agree). The final part captured the worker behaviour factor, which was composed of several indicators. The respondents were asked to rate the frequency of occurrence of each indicator using a six-point rating scale from 1 (never) to 6 (always).

The research employed the structural equation modelling (SEM) technique to analyse the data. The technique allows separate relationships for each of a set of dependent variables. It provides the appropriate and most efficient estimation techniques for a series of separate multiple regression equations estimated simultaneously (Hair *et al*. 1995). The first step in using the technique is to distinguish which independent variables predict each dependent variable by drawing upon theory, prior experience and the research objectives. Some dependent variables may become independent variables in subsequent relationships, giving rise to the interdependent nature of the structural model. Moreover, many of the same variables will affect each of the dependent variables, but with different effects. In the current research the structural model expresses the relationships between safety culture factors and worker behaviour, as shown in Figure 1.

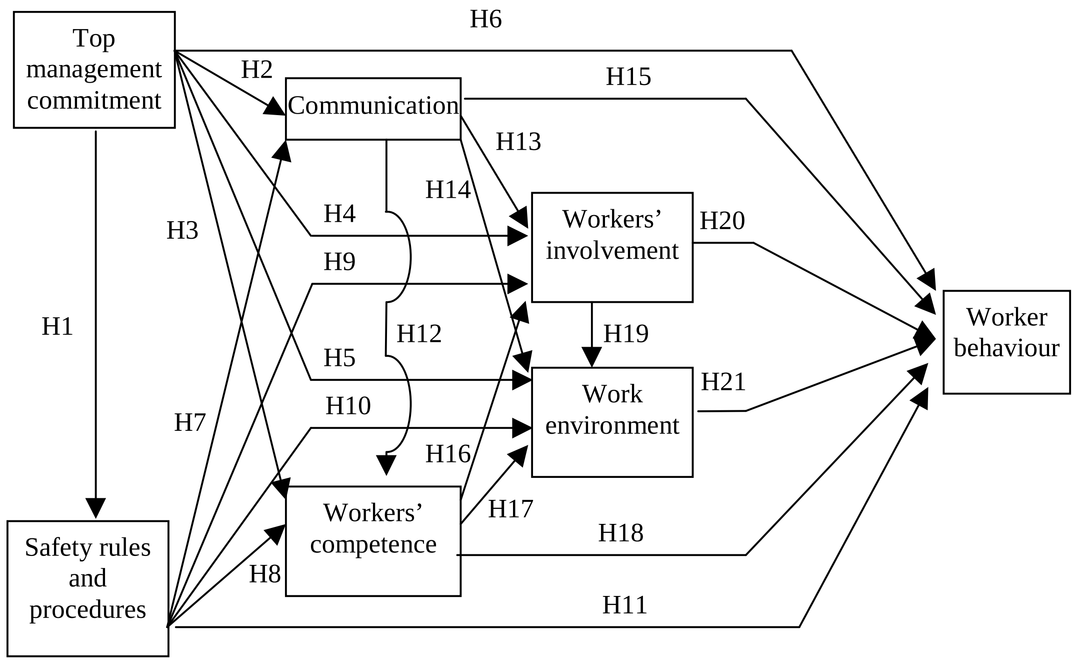


Figure 1: The *a priori* model

The analyses following the development of the *a priori* model (including factors and their respective indicators) were confirmatory factor analysis (i.e. to confirm that an indicator significantly indicates its respective latent factor), regression weight tests (i.e. to test whether the regression weight in each relationship is significantly not zero), model modification (if required), goodness-of-fit test (i.e. to evaluate the overall final model fit) and structural effects analyses (i.e. the strengths of direct, indirect and total effects between factors in the model).

RESULTS

Three ongoing construction projects at the time of the survey were approached. The projects included a shopping mall, office and clinic buildings. From these projects, a total of 207 valid questionnaires were successfully collected. The number of respondents gathered fulfilled the minimum requirement in using the SEM technique, i.e. five times the number of indicators.

CONFIRMATORY FACTOR ANALYSIS

In this step, each indicator was evaluated for its significance in contributing to its respective factor. The null hypothesis was that there was no significant contribution (α = 5%). The analyses performed showed three indicators of worker behaviour factors that were insignificant. They were then excluded from the model.

REGRESSION WEIGHT TEST

This step was to test each direct effect (21 paths) in the model. The null hypothesis was that there was no significant effect from one factor (e.g. top management commitment) to another factor (e.g. safety rules and procedures), with 95% confidence interval. Table 1 presents the analysis results. There are 11 paths that were insignificant (with p-value greater than 5%), and should be eliminated from the model.

Table 1: Regression weight test results

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**B**
Commitment (F1)	—	0.000*	0.006*	0.000*	0.260	0.330	0.747
Rules and procedures (F2)	—	—	0.000*	0.768	0.000*	0.272	0.000*
Communication (F3)	—	—	—	0.000*	0.000*	0.857	0.646
Competence (F4)	—	—	—	—	0.260	0.897	0.251
Involvement (F5)	—	—	—	—	—	0.000*	0.011*
Environment (F6)	—	—	—	—	—	—	0.379
Behaviour (B)	—	—	—	—	—	—	—

Note: *Significant influence (at α = 5%).

MODEL MODIFICATION

From the previous analysis results, the *a priori* model was modified. The new model (Figure 2) incorporated only 10 paths.

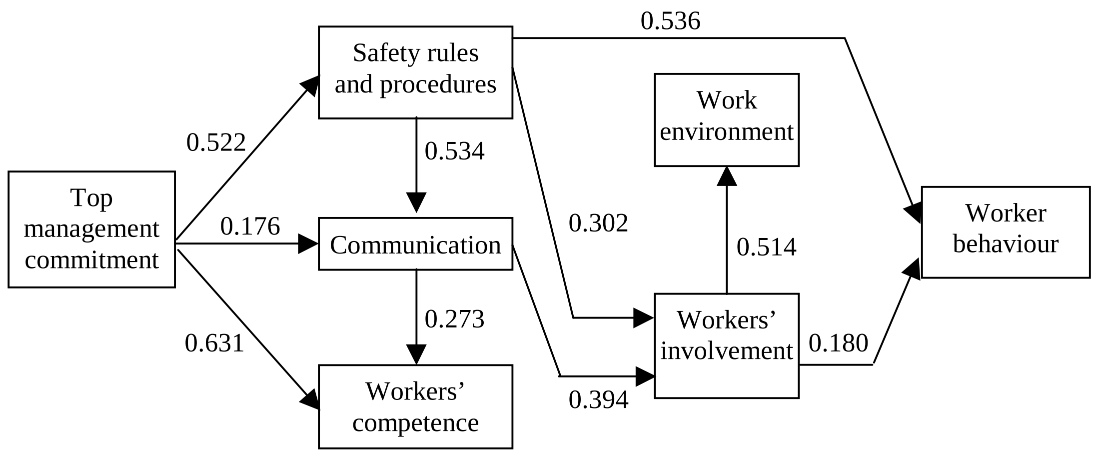


Figure 2: The new model

GOODNESS-OF-FIT TEST

The new model (Figure 2) was tested for its goodness-of-fit. Several indexes were used as shown in Table 2. It can be seen from the table that all indexes' value fulfils the condition for model fitting, thus the new model can be used as the basis for a description of the influence of safety culture upon worker behaviour.

STRUCTURAL EFFECTS ANALYSES

The strength of direct effects can be seen from Figure 2. Two safety culture factors directly influence worker behaviour, i.e. safety rules and procedures and workers involvement. Meanwhile, Table 2 presents the strengths of indirect effects in the model.

Table 2: Goodness-of-fit test results

Goodness-of-fit indexes	Test value	Condition		Remark
RMSEA	0.000	≤	0.08	Fit
GFI	0.987	≥	0.90	Fit
AGFI	0.968	≥	0.90	Fit
CMIN/DF	0.857	≤	2.00	Fit

Table 3: Indirect effects

	F1	F2	F3	F4	F5	F6	B
Commitment (F1)	—	0.000	0.295	0.129	0.352	0.181	0.359
Rules and procedures (F2)	—	—	0.000	0.146	0.210	0.263	0.092
Communication (F3)	—	—	—	0.000	0.000	0.202	0.071
Competence (F4)	—	—	—	—	0.000	0.000	0.000
Involvement (F5)	—	—	—	—	—	0.000	0.000
Environment (F6)	—	—	—	—	—	—	0.000
Behaviour (B)	—	—	—	—	—	—	—

MEAN DIFFERENCES ACROSS PROJECTS

Once the model has been properly established, further comparisons between groups (projects) were considered. In particular, whether or not projects differed in their average perceptions of safety culture was examined. MANOVA and one-way ANOVA tests were performed on the measured safety culture factors. MANOVA was used to test for the effects of the project on each safety culture factor. A Box test was first employed, showing that there were statistically significant differences between the variance–covariance matrices across the different projects (Box’s M = 270.93, F = 6.071, p = 0.000). Further multivariate analyses display significant differences between the projects (Wilks’ Lambda = 0.301, F = 27.273, p < 0.001; Pillai’s criterion = 0.811, F = 22.744, p < 0.001).

Several one-way ANOVAs were then performed one for each dimension. Table 4 shows four factors that were statistically significant different, i.e. top management commitment, safety rules and procedures, communication and workers’ competence. From the mean values, it can be seen that the mall project possessed a better safety culture than the two other projects, especially upon the aforementioned four significant factors.

Table 4: ANOVA results

Safety culture factors	Mean values			*F*	*Sig.*
	Mall	Clinic	Office		
Top management commitment	4.34	3.61	3.30	5.51	0.00
Safety rules and procedures	4.03	3.77	3.51	6.38	0.00
Communication	3.53	3.27	3.14	10.04	0.00
Workers competence	4.51	3.85	3.51	9.03	0.00
Working environment	3.58	3.57	2.71	1.89	0.15
Workers involvement	3.60	3.58	3.48	2.71	0.07

DISCUSSIONS

The analyses results through the structural equation modelling indicate that safety culture influences construction workers' behaviour. Factors that influence worker behaviour (direct and/or indirectly) are top management commitment, safety rules and procedures, communication and worker involvement. One important thing found from the analysis is that top management commitment is the driver to develop a good or poor safety culture. The finding thus strengthens previous assertions on the importance of management commitment (Turner 1992; Pidgeon 1998).

Another noteworthy finding is related to approaches in controlling worker behaviour. Reason (1997) mentions that worker behaviour can be controlled in two ways, i.e. prescriptive and discretionary; and mixed controls, where the choice of control depends on several aspects. The analysis results confirm that worker behaviour can be controlled through the combination of both approaches.

Prescriptive control can be described as external controls, which are made up of rules, regulations and procedures that closely prescribe what actions may be performed and how they should be carried out. Such paper-based controls embody the system's collective wisdom on how the work should be done. This approach is shown in Figure 4 by the direct influence line from safety rules and procedures to worker behaviour. In this way, worker behaviour can be controlled by forming safety rules and procedures that are appropriate, easy to understand and implemented by the workers. Workers then should follow the rules and procedures, and sanctions will be given for any violations.

On the other hand, discretionary controls are derived from the knowledge and principles through training and experience, which form the internal controls. This research shows that internal controls can be performed by enhancing workers' awareness towards the importance of safety. This can be done by involving and conducting a two-way communication with the workers about safety at work, and also giving safety training to increase the workers' knowledge and experience.

The mean scores in the three projects indicated that in general the workers' perception towards safety culture is quite good (mean score more than 3.00). However, there are significant differences between the three projects, where the mall project demonstrates the best safety culture. It is interesting to note that the clinic and office projects were performed by the same contractor organization. It can be said therefore that the contractor constructing the mall project possesses a better safety culture than the contractor on the two other projects.

CONCLUSIONS

The research has examined the influence of safety culture (and its factors) on workers' behaviour through structural equation modelling. The resulting model indicates that safety culture plays an important role in influencing workers' behaviour, through such factors as management commitment, safety rules and procedures, communications and workers' involvement. The model highlights management commitment as the first most important step in initiating appropriate safety culture. In addition, workers' behaviour can be controlled through the combination of prescriptive and discretionary approaches.

REFERENCES

Andi and Minato, T (2004) Representing causal mechanism of defective designs: exploration through case studies. *Construction Management and Economics*, **22**(2), 183–92.

Cheyne, A, Sue, C, Oliver, A and Tomas, J M (1998) Modelling safety climate in the prediction of levels of safety activity. *Work & Stress*, **12**(3), 255–71.

Cooper, M D (2000) Toward a model of safety culture. *Safety Science*, **36**, 111–36.

Hair, J F *et al*. (1995) *Multivariate data analysis with readings.* 4ed. Englewood Cliffs, N J: Prentice-Hall.

Hinze, J W (1997) *Construction safety*. Upper Saddle River, NJ: Prentice Hall, Inc.

Marsh, T W, Davies, R, Philips, R A, Duff, A R, Robertson, I T, Weyman, A and Cooper, M D (1998) The role of management commitment in determining the success of a behavioural safety intervention. *Journal of the Institution of Occupational Safety and Health*, **2**(2), 45–56.

Mohamed, S (2002) Safety climate in construction site environments. *Journal of Construction Engineering and Management*, **128**(5), 375–84.

Oliver, A, Cheyne, A, Tomas, J and Cox, S (2002) The effects of organizational and individual factors on occupational accidents. *Journal of Occupational and Organizational Psychology*, **75**, 473–88.

Pidgeon, N (1998) Safety culture: key theoretical issues. *Work & Stress*, **12**(3), 202–16.

Pipitsupaphol, T (2003) *Understanding effects of heuristic and biases on at-risk behaviour of construction workers*, Unpublished PhD Dissertation, University of Tokyo, Japan.

Reason, J (1990) *Human error*. Cambridge: Cambridge University Press.

Reason, J (1995) A systems approach to organizational errors. *Ergonomics*, **38**(8), 1708–21.

Reason, J (1997) *Managing the risks of organizational accidents*. Aldershot: Ashgate Publishing Limited.

Reason, J (2000) Human error: models and management. *Western Journal of Medicine*, **172**(6), 393–6.

Turner, B A (1992) The sociology of safety. *In*: D Blockley (Ed.) *Engineering safety*. London: McGraw Hill.

Uttal, B (1983) The corporate safety cultures, *Fortune Magazines*, 17 October.

MEASURES OF INFORMATION FLOW FOR LEAN DESIGN IN CIVIL ENGINEERING

Effi Tribelsky[1] and Rafael Sacks[2]

Civil and Environmental. Engineering, Technion – Israel Institute of Technology, Haifa 32000, Isreal

Research to date concerning application of lean thinking to civil engineering design suggests that applying the principles in a systematic fashion may improve the process, reduce errors and reduce negative iteration. However, there is a lack of any method for measuring information flow during the design process. This study proposes mapping and measuring the flow of information in the process of detailed design. Measures and indices of flow were formulated based on examination of empirical data compiled by monitoring flows of data and information in the detailed design stage of each of fourteen construction projects. The data was drawn from the computerized databases created through use by practitioners of an Internet-based construction project management tool. The indices and information flow graphs being developed are intended to assist in identifying faults or bottlenecks in the process as they happen, providing clear indications of disruptions in the information flow. As such, they are important tools for research of engineering design and for practical use in design management.

Keywords: measurement, information technology, design management, lean thinking, project management.

INTRODUCTION

Like most processes, the detailed design process for a civil engineering facility can be wasteful or efficient. Process efficiency is defined by the nature of the reciprocal activities between process participants, with a large measure of output effectiveness resulting from the desire to avoid unnecessary repetition of tasks. Process efficiency and outcome effectiveness are key issues in measuring the likelihood of success of a project. Achieving this requires measuring c[2]apabilities and relative scales to enable follow up and comparison between various activities, beginning at the single process level and up to a full and detailed process.

But how can we tell at any particular point in time that a design process wastes inputs and is not expected to yield optimum output? How can we tell if the flow of design information is efficient? Can we assemble and present a value flow path map dynamically, while the process is taking place?

The difficulty in providing a response to these questions is due to the lack of indices or tools to assist in analyzing and quantifying the progress in generating value along the information flow path. The research detailed in this paper aims to respond to this

[1] efit@technion.ac.il

difficulty by presenting a model for measuring information flow efficiency, and attempting to show the correlation between this and the final results of the project.

"Lean" production, which has its roots in the Japanese automobile manufacturing plants, found its way into many other manufacturing industries, worldwide. The method is centred on waste reduction and facilitating flow in various manufacturing processes (Ohno 1988; Womack *et al.* 1991). It has also impacted on the construction sector, and numerous researchers and practitioners have explored the possible practical implications on the industry (Alarcon *et al.* 2005; Ballard and Howell 2003; Josephson and Hammarlund 1999; Sacks *et al.* 2003).

Many studies have shown that there is no lack of waste, in its various forms, in civil engineering projects (Fayek *et al.* 2003; Koskela 2004); it can be found at all project stages and all managerial levels. Planning and managing the design process presents complicated managerial problems for project managers. Choosing the right team, outlining a work plan and controlling the performance of consultants are the major criteria determining the success or failure of a project.

Waste in engineering design has many facets, beginning with partial utilization of the engineering solution space and loss of opportunities, through wasteful management and up to creation of negative and ineffective design outputs. The scope of work repeated at building sites is conservatively estimated at 6% of the project value (Love *et al.* 2000); more than half of this rate results from various design failures. Implementing lean principles might help eliminate this effect, but there is no method for measuring the flows of information in the design process and the effectiveness of those flows. In the words of Sir William Thomson (Lord Kelvin) "If you cannot measure it, you cannot improve it."

Since many researchers worldwide have recognized that design contributes decisively to the success of the final product, a wide range of research has dealt with managing the process. Although most of the research has centred around manufacturing industries, such as the automobile industry, the aircraft industry and so on, a few researchers have studied design management in the construction sector. Most studies in this field deal with operational management of the design, and concentrate on management of design offices, their day to day operations and making processes efficient (Bashir and Thomson 1999; Chan and Yu 2005; Thomas *et al.* 1999). Only a few studies have dealt with value management and design flow with a content approach. How to improve information flow and design management in terms of cycle-times, batch sizes, intra-process reciprocal relationships and the quality of the information created have been studied to a lesser and more limited extent (Chang and Ibbs 1998; Thomson *et al.* 2006).

According to Formoso and Tzortzorpoulos (1998), the currently accepted design process doesn't necessarily reduce the ramifications of partial information and uncertainty, doesn't guarantee that the required information for completing the full design is sufficient, and doesn't reduce the level of non-correspondence between the various design documents. Ballard and Koskela (1998) point out that design managers try to deal with some of the above-mentioned problems using project management, concurrent engineering, process processing, value management, organization of multidisciplinary teams, and modern methods of electronic data transfer and data sharing. According to Ballard and Koskela (1998), with traditional design, preference is given to managing a sequence of tasks (using the critical path method) as opposed to flow and value management. The starting point of the process is the assumption that there is a single good planning response to each task. If the solution is complex, iterations are performed on the chosen solution until an agreed-upon solution is achieved. This approach reduces the solution horizon, leads to the loss of valuable time for the rest of the process, and damages the design process efficiency.

A major foundation of the lean management method is based on identifying the product flow route along the production path and mapping the product value amassing process along this path (Womack and Jones 1998). The design process is similar in nature to the production process (Ballard 2000), but while in the typical production process machines and workers produce tangible products, in the design process consultants and designers work together to translate ideas and needs into tenders and documents. Other differences are driven by the target function of the production system. While classical manufacturing production systems encourage minimization of variance among its products, and sees rework as waste, the design mechanism draws its power from continuous positive iteration and continuous improvement during the process. Nevertheless, the same features of flow, such as bottlenecks, batch size and control are observed in both design processes and production processes.

The accepted means of communication between project managers and consultant teams don't encourage flow continuity and don't support the utilization of the full possible solution space. Identifying and mapping information flow channels in design projects and exposing designers' behaviour patterns would allow identification and neutralizing of focal points of waste and identification of the major locations where increase in value takes place, as well as consolidating communication methods in order to fully utilize the design process and improve its flow.

The following sections explain the aims and method of the research, describe a procedure for mapping information flows, propose a set of indices, and present initial conclusions of the research to date.

AIMS AND METHODS

This study aims to provide a set of measures and indexes designed to assist in quantifying information flow during the design process of a constructed facility. Use of these measures and indexes is intended to help project managers and participants identify bottlenecks, large batch sizes and long cycle times in the process as it progresses. Providing the clarity of visualization of the value flow path of the product design may enable short-term corrective action or long-term re-engineering of design processes.

The research method comprised 5 stages:

1) Examination of typical information flow patterns during detailed design. To this end, 14 various projects were selected and their information flows were recorded and studied.
2) Identification of the raw data that could be used as a basis for computation of measurement indices. From this, the units of measurement were defined.
3) Definition and preparation of information flow maps in order to visualize information flows.
4) Formulation of information flow indices and methods for their computation.
5) Validation of the indices by measurement using the project data measured, and comparison of the flow patterns revealed in light of actual project outcomes.

The following sections describe each of the first four steps; the fifth stage is currently in progress.

PROJECT DATA COLLECTION

Detailed data was collected from fourteen projects in order to provide a basis for proposing an array of indices. The indices measure rates and patterns of generation of design information, dissemination, batching, and other features. The projects examined were all part of an airport relocation. The whole project, whose total cost is estimated at $250M, included runways, hangars, service facilities, technical areas, flight infrastructures, water and sewage infrastructures, operational infrastructures, electrical systems, communication power stations, facilities, fuel lines, administrative areas and living quarters. Since all the projects were managed by the same developer, they had similar profiles, making it easier to compare the different projects. However, each project had a different team, including the designers and managers, thus allowing each project to be taken as a separate case.

Data was collected on three complementary levels (see Figure 1), so that the indices proposed could be verified by computing and comparing their values for the separate data sets collected for each project. The first level was retrieval of data describing information flow from the information transfer data log compiled automatically by the @View project management intranet application used to manage the projects (www.atview.com, Ramdor 2006). The software enables the use of the internet for centralized management of all project information, including CAD files, meeting summaries, presentations, time tables, task assignments and additional information. The record of uploads and downloads of files and any views of them that is saved in the journal log includes the time at which the activity was performed, the names of those who carried it out, and the file names where relevant. The data covers a wide range of the information transactions performed in the project. The activity types were divided into six categories: uploading, updating the version of, viewing, erasing, moving and copying files. Using the journal logs enabled collection of a large sample of documented, detailed and reliable information over extended periods.

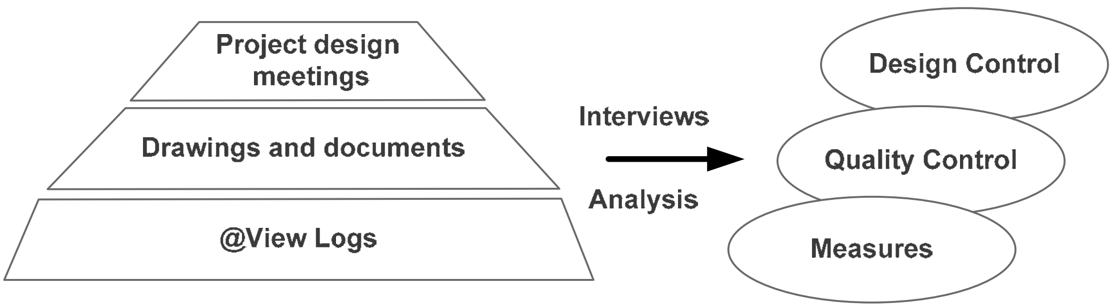


Figure 1: The three information sources, processing methods and validation systems

Understanding the value accumulation mechanism of design outcomes along the information flow path requires in depth analysis of the project drawings; this is the second level of data collection. The information management systems built into the @View software maintain all the versions of every drawing that was uploaded to the system throughout the life of the project. By comparing a drawing version to its predecessor, and by tracking the changes in the drawings by using view and compare software such as Autovue (www.cimmetry.com, Cimmetry Systems 2006), the nature and quality of all of the changes made can be examined. Mapping the changes in drawings, identifying the motivation for making them, and estimating their influence on information flow, helped to sort information movements and allowed the development of flow indices based on the information content that could not be based on the movements recorded in the journal logs. The third level was a series of structured observations of 86 design progress meetings that took place in the projects. The observations allowed collection of complementary information concerning design contents and contexts, the manner in which the meetings took place, difficulties during the formulation of the solution, the dynamics of the participants and their activities, and the general progress of the each project. Data collection, examination and analysis assisted in creating indices of the flow, and in defining the impact of the background conditions which influenced the quality of the information flow and the success of the projects. A structured and detailed method for measuring the influence of background conditions on the information flow was proposed in this study but is beyond the scope of this paper.

INFORMATION MEASURES

Figure 2 shows the different views of the same information object and demonstrate the difference between one information object to another.

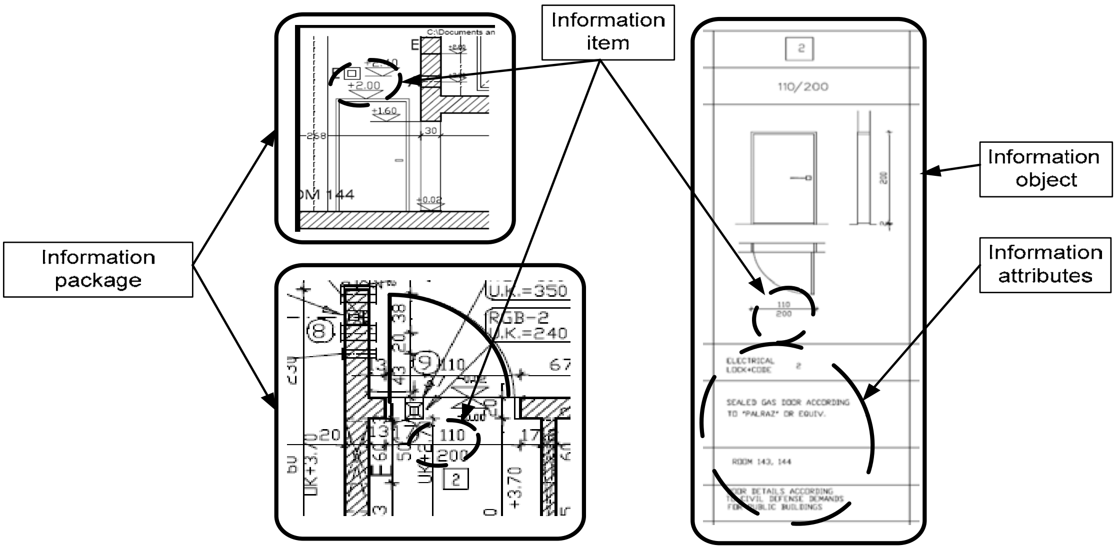


Figure 2: Graphical representation of types of information data

1. An *information package* is a view in a drawing, a text document, worksheet or data table, a page of calculations, etc., whether on a printed page or in a computer file. Where 2D CAD drawings are the medium of communication – which is still the most common method in civil engineering design – information packages are the basic units that are transferred between design project team members. If BIM is used, the information package could represent an entire model.
2. An *information item* is a single piece of information. It may be textual (a number in a bill of quantity, a label or dimension on a drawing, a clauses in a specification) or graphic (a line, arc or hatching in a drawing). An information package therefore represents a set of information items.
3. An *information object* is a distinct component of a building or facility with technical and engineering attributes and characteristics. In the literature, objects

are defined as having form, function and behaviour. Most objects are tangible, such as ceilings, windows, chillers, pipes, cables, walls, beams, etc., but some are intangible, such as space, passageway, etc. In projects where 2D drawings are the medium of communication, information objects are defined through their depictions in drawings, lists and other documents – i.e. in information packages. Each information object will commonly appear in multiple information packages.

4. An *information attribute* is a technical, engineering or management attribute of an information object such as its dimensions, material type, supplier name, colour, price, etc. The value of an information attribute may be displayed in any number of information packages.
5. An *action* is performed by a team member to communicate information. This most commonly involves transfer in one form or another of an information package, such as uploading a file to a central project server, delivering a paper document or similar activity. In some instances individual information items are communicated, such as when a single attribute is conveyed in discussion. A *publication* action is the transfer of any information from the private to the public domain, accomplished by posting it in a location accessible to relevant project participants.
6. A *project event* is an event in a project's lifecycle at which there is a peak in demand for information. Examples are preplanning meetings, design coordination meetings and presentations.

MAPPING INFORMATION FLOWS

The information flow graphs (IFGs) shown in Figure 3 and Figure 4 are based on the information transactions registered in the journal logs of the project intranet software and on the outcomes of the process analyses. The maps describe the information exchange between project participants while emphasizing information transfer, its trend and purpose.

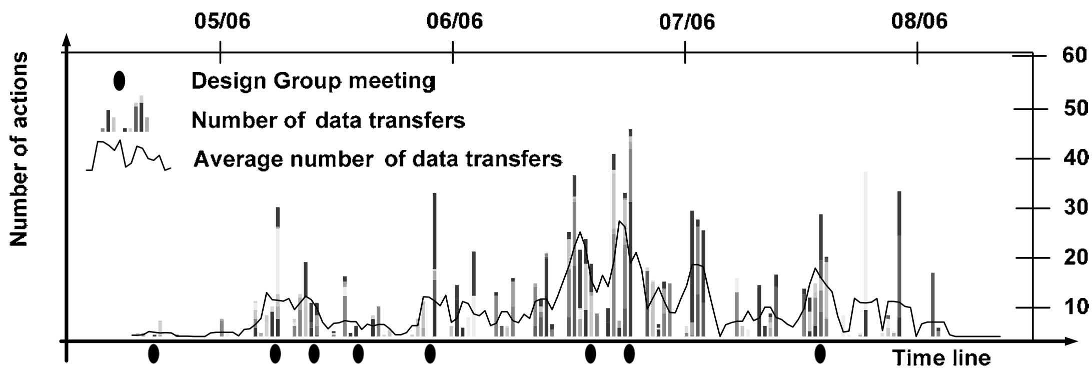


Figure 3: Graphical representation of IFG (Information Flow Graph) – data transfer density
The graph is displayed to managers with colour-coding according to design discipline.

The graph shown in Figure 3 demonstrates the handling time for transmitted information, assists in estimating information batches, reveals bottlenecks, and assists in identifying inadequate behaviour of consultants; it is a tool in the hands of the project manager for identifying obstructions and failures during the design process.

The IFGs' enable visualization of the nature of the process, how it progresses and how and when the information exchanges are performed. Identifying large batches, finding

unnecessary handling delays and late responses are just some of the insights that can be achieved by viewing the map. Planning the process using the flow map, and performance vs. planning control, will enable measure most of unique activity characteristics for the design process and will be used as a qualitative tool during the entire
process.

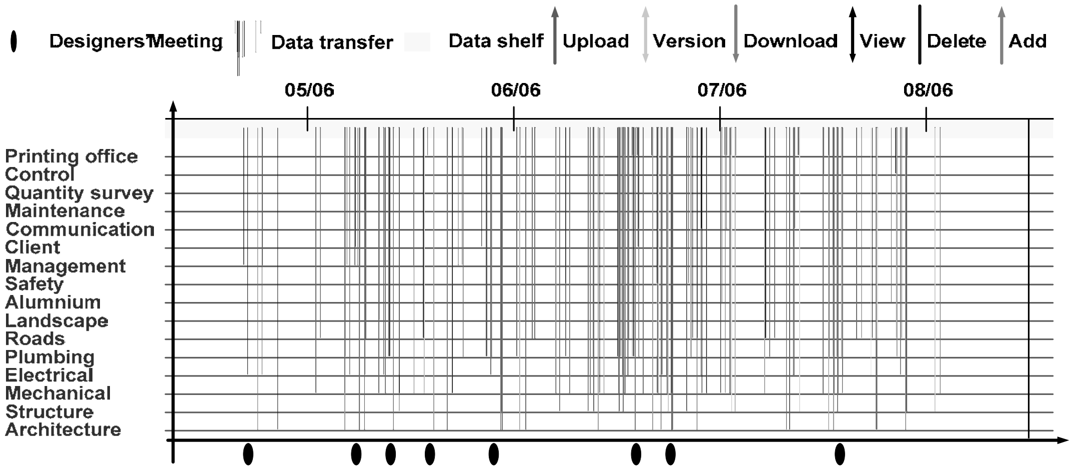


Figure 4: Graphical representation of IFG – number of data transfer actions

INFORMATION FLOW INDICES

Eight central indices were developed to assist in quantifying and characterizing information flow in the project. They are summarized Table 1**.** The following sections are dedicated to a general description of those indices. The indices make use of the technical terminology detailed above, to describe the type of information transferred, its nature and scope.

Table 1: Measures of information flow

	Index	Description	Symbol
(a)	Acts Frequency	Examine the frequency of usage of a project's information packages	AFr
(b)	Information Package Size	Examine and quantify the level of detail of information packages	IPS
(c)	Batch Size	Describe the volume of information batch transferred	BSz
(d)	Batch Rhythm	Describe the rhythm in which the information batches transferred	BRy
(e)	Turbulence	Define the nature of the flow	Tur
(f)	Information Development Velocity	Define the speed and rate of information expansion	IDV
(g)	Rework	Examine the amount and nature of designers rework	Rew
(h)	Bottlenecks	Define weakest work station in the process	Bot

Activity Frequency

The activity frequency index describes the frequency of usage of a project's information packages, i.e. the rate at which information transfer and information treatment events take place. Alternatively, we can say that the index describes the frequency with which any processing activity (viewing, loading, presentation, erasure, update, attachment, etc.) takes place for information packages (drafting files, meeting summaries, presentations, bills of quantity, building information modelling (BIM) type objects, and so on).

Even though the information development process may be continuous within each design office, taking place over time, the information accumulated has no utility for the rest of the team until it is made available to others. It can be considered to be hidden and inapplicable. Only when information is made available to all those requiring it, does it obtain value and provide benefit to the entire project.

Due to the nature of the tools and practices common in the process of civil engineering design, information packages are usually transferred in batches, their content and completeness varying from batch to batch. The optimum values for the size of batches and the frequency of their publication depend, to a large extent, on the type of project, the number of designers involved, and the way the project is managed. The number of ways of grouping information in batches in a project is essentially unlimited. The sorting method and the choice of batch criteria have a considerable influence on the behaviour of the index and accordingly on the conclusions reached from its analysis.

$NOA_{i,j}$ - Total number of actions carried out on the information batches on day i in batch j

TTP_j - Total time period in which measured j batch (days)

NOS_j - Number of sections into which the total time period of j batch is divided

Index Sensitivity $$S_j = \frac{TTP_j}{NOS_j}$$

Actions Frequency in batch j on day i $$AFr_{i,j} = \sum_{i=-S}^{S} \frac{NOA_{i,j}}{2S+1}$$

Average actions Frequency in batch j on day i [act\day] $$\overline{AFr}_j = \sum_{i=S+1}^{n-S-1} \frac{AFr_{i,j}}{n-2S}$$

The standard deviation will be used as a statistical index for describing the scattering of values of a data group around their average.

Standard deviation of actions frequency in batch j $$\sigma_j = \pm\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(AFr_{i,j} - \overline{AFr}_j\right)^2}$$

Information Package Size

The information package size index is intended to examine and quantify the level of detail of information packages, and to allow comparison to the total number of items in order to demonstrate the level of completeness of packages of transferred material. It would be convenient to use an automated count such as the physical size of the information package (number of words, number of graphic objects, number of dimensions, file size in kB, or similar), but these do not accurately reflect the information content of a package. A change in the physical size of an information package doesn't necessarily result in addition or reduction to the scope of transferred information. In addition, occasionally reducing the package size embodies positive design progress and vice versa. For this reason, the index is based on counting information units. The index can be formulated on two levels of detail: by counting the number of information objects in an information package, or by counting the number of information items in the package.

The package size can be used to monitor the pace of accumulation of new information in either relative or absolute terms. In relative terms, the information package size can be compared with the size of an earlier version of the same package to determine a percent increase. However, if a measure of the completeness of a package is needed, an absolute measure can be used, but this can only be done if the final required information package size can be estimated. A final size might be set using specific sampling of archived packages, by estimating the maturity of the package at any stage, or by careful planning the information content required for each package.

Where the same information objects are reflected in multiple information packages, the count of information items across packages may be misleading, reflecting increasing package size where in fact it is only the same information being recorded more times. Thus the index may show growth even when no real information is being added. One way to avoid this pitfall is to select a small number of representative packages for measurement instead of using all of the packages. For example, for a building, floor plans can be used while sections and elevations are excluded.

Batch Size

Efficient information transfer isn't necessarily dependent on the size of an individual information package or on the effective number of information unit (objects or items) it contains. Sometimes, the need to transfer complete and comprehensive information on the one hand, or to focus on a narrow subject on the other hand, determines the volume of the transfer, the efficiency of the transfer and as a result the value added to the project.

The batch size index is a quantitative and qualitative index intended to describe the volume of information transferred by an individual designer or consultant in a single, short and sealed pulse. This reflects the quantity of information accumulated by that participant in the time period since their previous delivery of information. The index is also used to quantify and examine the number of information packages that the batch contains. In a similar manner to the information package index, the batch size index can be formulated on two levels of detail, i.e. the number of information *objects* or the number of information *items* transferred in each batch.

Batch Rhythm

Measuring the rhythm of the batches is intended to show another facet of project information flow. By identification of the project events dates, measuring the total number of actions that were carried out between those events, calculating frequencies of batches and tracing anomalies in their appearances, it is possible to measure this index. On the one hand, the rhythm of the information transfer patterns may shed light on the performance of the project team, its efficiency and dedication to the project. On the other hand, they may give an indication of how the developer and project manager function, and the maturity of the project plans.

An analysis of the harmony of information package movement may shed light on the activities of the team members, the correlation between providing and using internal project information and the influence of external interference. Disharmonic activities may be an indication of failures in their execution, indicating those responsible and possible directions for improvement.

Turbulence
Turbulent flow is defined in fluid mechanics as the motion of a fluid whose velocity at any point along the flow line fluctuates at an unsteady rate and in an irregular fashion. This is in contrast to laminar flow, where the fluid is considered as consisting of many very thin layers, moving parallel to one another, at a uniform velocity, uniform rate and within a uniform flow direction. In order to determine the nature of the flow in a typical cross-section, use is made of a Reynolds number. By computing the ratio of the fluid's inertial forces to the frictional forces acting between the fluid and it's surroundings and comparing them to known values, one can determine if the flow is turbulent or laminar.

In a similar fashion (Fyall 2002) information flow can be characterized and defined using parameters describing the velocity of material transfer, type of typical project, wealth of information inherent in the information package, number of package versions, etc. Examining information flow paths, calculating the turbulence index and comparing the results to known values will assist in defining the nature of the flow and will help set project managers in the right direction.

The evaluation of the turbulence index is based on the calculation of the information density, estimation of the development rate of the information units, and using a constant adjusted to the project type.

Information Development velocity
This measure is calculated by dividing the growth in size of information packages by the time gap over which it occurs. The development velocity characterises designers' behaviour and reveals the information flow paths. It also enables identification of crises when they occur. The index is influenced by the pace of information exposure to the public domain and by the degree of completeness at the time it is calculated. Since it is impossible to calculate the end value of the information precisely at the beginning of the design process, the index's variables were selected in a manner that allows reevaluation during the course of the design process.

Rework
Although to most managers the term "rework" carries negative connotations, it can have value in the design process. The rework measure reveals the amount of rework in the design process and categorizes it according to its origin and contribution to the complete information value measured at the end of the process. It assists in determining the degree of changes made in the design and clarifying their origin. Tracking the sources of rework will allow project manager to find out its causes, control its effects and mange its appearance in order to achieve the best benefit and value to the project.

Bottlenecks
The max-flow min-cut theorem taken from graph theory demonstrates how the maximal amount of flow that can be transferred in a flow network is equal to the minimal capacity of any network cross-section. In an equivalent manner, we can assume that the overall performance of a production system will be limited for the upper production threshold of the weakest work station in the process (Goldratt and Cox 1993; Hopp and Spearman 2001).

In a manufacturing plant, production at full capacity at a production station may lead to the accumulation of inventory in the process at the work station and at the same time to the creation of unnecessary burden on the production station in the upstream flow. Bottlenecks can be detected by examining the production floor and identifying inventory waiting to be processed at the work station.

As explained in the introduction above, the same features of flow, such as bottlenecks, batch size and control are observed in both detailed design processes and production processes. For example, we can identify bottlenecks along the design chain where the team doesn't function for various reasons, or where external workloads on an individual designer prevent progress. Identifying these points by locating unusual information transfer and tracing anomalous behaviour can help managing their causes and assist in smoothing out the process and improving project outcomes.

CONCLUSIONS

The main contribution of this research can be expressed in terms of improvement in multidisciplinary civil engineering project outcomes by promoting understanding of the functioning of the design environment and by instilling practical measures as the basis for better management of all the functions involved in the project. Quantifying measures of information flow is achieved using predefined flow indices. Automating data collection for the indices and creating simple techniques for implementation will make it easier to use the method in the framework of the continuous activities of any project.

In spite of the fact that design management is an important element in influencing project performance, the accepted process planning methods are taken principally from the performance field and are not entirely suited for an essentially iterative process such as design. Using the suggested indices and assistance tools/agents for analyzing and quantifying the value amassing progression along the information flow path, can help design managers deal with the difficulties in planning, controlling and managing the process.

Creating a mechanism to assist in monitoring the influence of abstract processes may cause concern about creating a baseless sense of control of the project among project managers and team members. Yet, a careful use of the suggested model for measuring efficiency of information flow, and finding the correlation between this and the final results of the project, will improve the project outputs and deepen the knowledge and understanding of progress in the design environment altogether. Implementing a management and planning method based on lean management principles and the model may provide an alternative route for planning in the design process, for controlling it in real-time, and for learning lessons which will serve interested parties in the future.

The next stage of the research will deal with validating and calibrating the indices based on their application to the projects and examining their values in relation to the measures of success of the projects. Determining project success will be done by analyzing design control documents, examining time schedules of the project and comparing them to the original time schedule, researching the changes and additions made during the implementation and examining the suitability of the final product to the client's expectations.

In the future, the results of the study might become the basis for the reinforcement or refutation of current concepts for managing an array of consultants and designers, and determining an objective model for value appraisal.

REFERENCES

Alarcon, L F, Diethelm, S, Rojo, O and Calderon, R. Assessing the impacts of implementing lean construction. *13th Conference of the International Group for Lean Construction*, Sydney, Australia, 387–393.

Ballard, G. Managing work flow on design projects. *CIB W-96 Architectural Management International Conference, S.A.A.M. (The Society for the Advancement of Architectural Management)*, Atlanta.

Ballard, G and Howell, G A (2003) Lean project management. *Building Research and Information*, **31**(2), 119–133.

Ballard, G and Koskela, L. On the agenda of design management research. *Sixth Annual Conference of the International Group for Lean Construction (IGLC-6)*, Guaruja, Brazil, 12.

Bashir, H A and Thomson, V (1999) Metrics for design projects: a review. *Design Studies*, **20**(3), 263–277.

Chan, E H W and Yu, A T W (2005) Contract strategy for design management in the design and build system. *International Journal of Project Management*, **23**(8), 630–639.

Chang, A S and Ibbs, C W (1998) Development of consultant performance measures for design projects. *Project Management Journal*, **29**(2), 39.

Fayek, A R, Dissanayake, M and Campero, O (2003) Measuring and classifying construction field rework - a pilot study. Department of Civil and Environmental Engineering, University of Alberta, Edmonton, Alta.

Formoso, C T, Tzortzopoulos, P, Jobin, M and Liedtke, R. Developing a protocol for managing the design process in the building industry. *Sixth Annual Conference of the International Group for Lean Construction (IGLC-6)*, Guaruja, Brazil.

Fyall, M (2002) When project information flow becomes turbulent: toward an organizational Reynolds number. *138*, Stanford University.

Goldratt, E M and Cox, J (1993) *The goal: a process of ongoing improvement* Aldershot: Gower.

Hopp, W J and Spearman, M L (2001) *Factory physics, foundation of manufacturing management*. Irwin McGraw-Hill.

Josephson, P E and Hammarlund, Y (1999) The causes and costs of defects in construction: a study of seven building projects. *Automation in Construction*, 8, 681–687.

Koskela, L. Making-do – the eighth category of waste. *12th Annual Conference on Lean Construction*, Elsinore, Denmark.

Love, P E D, Mandal, P, Smith, J and Li, H (2000) Modelling the dynamics of design error induced rework in construction. *Construction Management & Economics*, **18**(5), 567–574.

Ohno, T (1988) *Toyota production system: beyond large-scale production*. Cambridge: Productivity Press.

Sacks, R, Eastman, C E and Lee, G (2003) Process improvements in precast concrete construction using top-down parametric 3-D computer modeling. *PCI Journal*, **47**(3), 46–55.

Thomas, H R, Korte, Q C, Sanvido, V E and Parfitt, M K (1999) Conceptual model for measuring productivity of design and engineering. *Journal of Architectural Engineering*, **5**(1), 1–7.

Thomson, D S, Austin, S A, Root, D S, Thorpe, A and Hammond, J W (2006) A problem-solving approach to value-adding decision making in construction design. *Engineering, Construction and Architectural Management*, **13**(1), 43–61.

Womack, J P, Jones, D T and Roos, D (1991) *The machine that changed the world*. New York: Harper Business.

THE VALUE OF CONSTRUCTION MANAGEMENT JOURNALS TO SUBMITTING AUTHORS

Bo-Christer Björk[1] and Jan Bröchner[2]

[1]*Department of Management and Organisation, Swedish School of Economics and Business Administration, PO Box 479, Helsinki 00101, Finland*
[2]*Department of Technology Management and Economics, Chalmers University of Technology, SE-41126 Göteborg, Sweden*

Publishers of academic journals can be seen as service providers to authors, in addition to their traditional role of providers of research results to readers. When submitting their manuscripts to journals authors make choices that may have career consequences for them as academics, and they would benefit from better information about the service characteristics of the journals they choose between. The purpose of this study was to analyse author perceptions of leading journals in construction management. Seven journals were identified and for each 2006 article, one author email address was extracted. A web-based questionnaire was sent to 397 authors and 35% responded. It was found that there was a core of three journals, regularly followed by at least half the respondents. These are journals that fulfil the criterion of 'relevant readership', which respondents ranked very high among service characteristics. Most of the other four journals have scopes broader than construction management and receive lower scores for characteristics such as impact on researchers. No open access journals were included, and authors in the field of construction management rarely post openly accessible copies of their manuscripts or publications on the web.

Keywords: authors, journals, open access, readership.

INTRODUCTION

Every time academic authors submit a manuscript to a particular peer reviewed scholarly journal, they are making an important decision which may have repercussions on their future careers. In choosing a particular journal the author is in fact making an investment decision. A bad choice will result in a poor return rate on the time and effort spent on the underlying research; a good choice may enhance reputation and the impact of the research presented in the manuscript. Economists have even calculated the discounted present value of publishing in a prestigious journal, in terms of future higher salaries, which helps explain why academic authors as a rule donate the fruits of their labour to scientific publishers. The fact of the matter is that academics barter their products for services rendered by the publishers. In this regard journal publishers are service providers to authors just as much as content providers to readers. Because of this situation, and because there is no price differentiation between bad and good manuscripts, the competition for good manuscripts is sometimes fierce, as experienced in the proliferation of calls for special issues.

[1] bo-christer.bjork@hanken.fi

In most other situations where consumers or companies face economic choices such as choosing between cars or home cinema equipment they are able to find a lot of data and market comparisons to help them make informed choices. This is not the case in the scientific journal market. How many of us know the number of subscribers or today, more importantly, the size of readership of the journals we submit to? If the publishers are asked for these data they usually regard them as trade secrets, partly motivated by the fear that low numbers would scare potential authors. Equally authors often have only a vague feeling for the rejection rates of journals. The only measurable factors that are well known are whether the journal is indexed by the ISI or not, and if it is, what its impact factor is.

Despite the lack of robust data on the performance of journals the 'invisible colleges' of a particular research field usually have established ranking orders of the journals in the field, whether unofficial or published ones. These are usually based on an assessment of the rigour of the review process of a journal and the academic quality of its papers. Sporadically, there have been studies of construction management journals. A pioneering study of the first decade of articles in *Construction Management and Economics* was published by Betts and Lansley in 1993, who also analysed the *International Journal of Project Management* (Betts and Lansley 1995). Chau (1997) ranked 22 construction management journals based on email responses from the CNBR network. More recently, Pietroforte and Stefani (2004) have analysed contents in articles published in the *ASCE Journal of Construction Engineering and Management*. Recently, Adeli (2007) discussed ISI impact factors for journals in a closely related field, civil and infrastructure engineering research.

Aspects not usually taken into account in traditional rankings are the speed of publication (from submission to publication) and how well the journals are reaching out to practitioners. Such factors can be important in fast-moving fields such as biotechnology or IT.

The purpose of this study is to analyse author perceptions of leading journals in construction management and author attitudes to open access publishing. An email survey with a web questionnaire has been made, and the responses are analysed. Finally, we discuss the outlook for open access and its consequences for construction management authors.

RESEARCH METHOD

Björk *et al*. (2006) have designed a methodology for benchmarking scientific journals from the submitting author's viewpoint. The methodology has been initially tested on construction IT journals and proposes the use of four different data collection methods:

1. Data openly and directly available in printed issues and from the websites of publishers, for instance subscription rates of journals.
2. Data available openly but which need to be calculated. In some journals the submission dates for articles are given in the published articles. From these data the average time from submission to publication can be calculated.
3. Data which can be obtained from publishers. Typical examples would be number of paper issues printed, usage statistics for web downloads.

4. Asking authors about their experiences with journals and perceptions of different journals. This method is excellent for instance to find out about the service level of the journals to authors.

The earlier study by Björk *et al*. (2005) on construction IT journals used methods (1) and (2) above. The present study of journals in the field of construction management and economics relies on the fourth method, asking authors in the field.

Our author-based survey proceeded in several stages. First, the relevant set of journals had to be defined. Initially, four top journals in the field of construction management were chosen: *Construction Management and Economics* (CME); *Journal of Construction Engineering and Management* (JCEM); *Engineering, Construction and Architectural Management* (ECAM); *Building Research and Information* (BRI; in this case, only articles of a CM content). Using Google Scholar for construction management articles in BRI and for all articles in CME and ECAM, while Scopus was relied on for JCEM (where the Google Scholar chronology errs), the five authors for each journal with the most cited articles published 2000–04 were identified. Two of the five most cited CME authors are also among the five most cited ECAM authors; the following two most cited ECAM authors have been brought into the analysis, given a total of 20 authors.

Next, since a main idea of this investigation is to support authors when they are choosing between publication outlets, for each of the 20 authors, their (up to) five other journals with their most cited articles published elsewhere have been identified using Google Scholar and the same time period, 2000–04. All of these authors had not appeared in all five of the other journals, but most of them actually had.

The final criteria for selecting among 41 journals thus identified in addition to the four initially chosen were that at least three of the top five cited authors among the original set of four journals appear with highly cited articles in the journal; the journal should primarily aim at an academic readership; and that construction management should belong to the core area of the journal.

Applying these criteria raises the number of journals from four to seven (see Table 1).

Table 1: Selected journals

Journal	**Publisher**	**Number of articles (2006)**
Automation in Construction (AIC)	Elsevier	65
Building Research and Information (BRI)	Taylor & Francis	44
Construction Innovation (CI)	Emerald	16
Construction Management and Economics (CME)	Taylor & Francis	107
Engineering, Construction and Architectural Management (ECAM)	Emerald	36
International Journal of Project Management (IJPM)	Elsevier	72
Journal of Construction Engineering and Management (JCEM)	ASCE	135

The second stage was the identification of authors. The total number of articles published in 2006 was 475 for the seven journals, and for each article, an email address to the corresponding author was recorded (alternatively the first author with an email address given in the article; exceptionally, when no email address was given, an author email address was located on the web). After deleting multiple occurrences of author names, 397 author addresses were located.

A web questionnaire was designed with 21 questions, including six with five-degree Likert scales. Emails with links to the questionnaire were sent out in February 2007, and after one reminder, a total of 140 answers had been received, corresponding to a 35% response rate. Error messages were received for 8% of the email addresses.

RESULTS

Respondent profiles

The personal information provided by the 140 respondents shows that an overwhelming majority (93%) are university employees, although five respondents are employed by private companies and the remaining five by other organizations outside the university system. Almost half (41%) of respondents in academia are employed in a permanent professorial position, and the same percentage applies to those in untenured positions; in addition, 10% are PhD students. There is a good spread geographically with authors from no fewer than 39 countries being represented; US responses make up 19% of the total, followed by the UK (14%), Australia (8%) and China (7%). In regional terms, both the European continent (4%) and Africa (4%) are comparatively poorly represented.

Readership of journal articles

Respondents were asked about the number of scientific articles they either browse through or read in detail per year. The overwhelming majority browsed through 20–199 articles: 21% browsed through 20–49, 27% 50–99 and 17% 100–199 articles. For full reading the majority of respondents belonged to the 10–99 articles range, where 29% read 10–19, 28% read 20–49 and 21% read 50–99. An earlier study by Björk and Turk (2000) of researchers in construction IT and construction management showed that academics in these fields browse through or read in detail 107 papers per year, which is in accordance with the present results.

However, this can be contrasted with data provided by Tenopir and King (2000), who have made extensive longitudinal studies over multiple research fields. They have found that academics report on average 370 hours per year reading and that university-based academics read on average 188 articles per year. The latter figure is higher than our study shows for construction management authors. There are some possible explanations for this discrepancy. First, Tenopir and King talk of ‘reading going beyond the contents page, title and abstract to the text of the document’, leaving to interpretation whether it is closer to browsing through or reading in detail. The second explanation is that scientific fields differ in their dependence on various publication channels. In some fields publishing is highly concentrated on journal articles, while in others such as construction management conference publishing, monographs and technical reports are frequent.

Criteria for choice of journal

Respondent were asked what relative weight (on a Likert scale of 1–5) they attached to a number of factors when choosing where to submit a manuscript. The results are shown in Table 2. Not surprisingly, ‘high academic status’ receives the highest score (4.5 average). But more interestingly number two on the list, ‘relevant readership’ (4.0) is felt to be much more important than large circulation. Although respondent interpretations of ‘academic status’ and ‘relevance’ may vary, we interpret this as showing that the authors care less about reaching a wide audience than being read by the core CM academic community, where they hope to have an impact on peers with their results. The fact that many authors seem to care little about articles being 'available freely on the web' (2.3), which could increase readership outside the core community, supports this interpretation.

Table 2: Criteria for choice of journal when submitting a paper

Criteria	Average score
High academic status	4.5
Relevant readership	4.0
Journal indexed by the ISI	3.5
Short lead time from submission to publication	3.4
Likelihood of acceptance	3.3
Large circulation	3.2
Level of impact factor (for ISI indexed journals)	3.1
Journal recommendation from author's university	2.9
Journal articles freely available on the web	2.3

Two more pragmatic variables affecting the fate of a submission, namely likelihood of acceptance (3.3) and short lead time from submission to final publication (3.5) seem to matter considerably to authors. Nevertheless, this is where there is usually a lack of available statistics and authors have to rely on word of mouth or guesswork.

Finally the factors immediately connected to the reward systems of universities, tenure, committees, etc., have medium importance on average. These include ISI indexing (3.4), level of impact factors (3.0) and journal recommendation from the author's university (2.9). It is suggestive that ISI indexing as such is deemed more important than the actual level of the journal impact factor, which would be a better indicator of the quality of a journal. This downplaying of the impact factor may have to do with the fact that, in contrast with most other research fields, few of the journals and conferences in which CM authors publish are indexed by the ISI and also that the impact factors of most indexed journals within this field are low, reflecting that there are no clear top journals according to the impact factor criterion. This is unlike research fields such as management science or information systems where top journals with high impact factors have emerged.

Readership and impact of the journals in the sample

When asked about how often they read each of the seven journals identified in the survey, three journals (CME, JCEM and IJPM) emerged as 'core journals' that at least half the respondents follow regularly (Table 3). The other four journals, which also cover topic areas other than the central construction management and economics ones, were less regularly followed and unknown to a higher proportion of authors.

Table 3: Reader habits and impact assessment (% of responding authors)

Variables	AIC	BRI	CI	CME	ECAM	IJPM	JCEM
Not familiar with journal	42	36	49	11	31	19	16
Read regularly or almost regularly	23	23	11	57	28	47	66
Impact on researchers of articles in the journal							
Don't know	*51*	*45*	*57*	*21*	*39*	*28*	*26*
For those who know: High, or almost high (4–5 on the 5-degree scale)	48	46	20	81	49	61	86
Career value of publishing in the journal							
Don't know	*48*	*44*	*54*	*21*	*38*	*27*	*26*
For those who know: High, or almost high (4–5 on the 5-degree scale)	47	49	31	73	55	60	85

Owing to the high proportion of answers revealing a lack of knowledge with the service characteristics of any of the seven journals, the following figures should be treated with caution.

Across journals, there is a broad similarity in the number of respondents who are familiar or unfamiliar with the impact and career value of choosing a particular journal.

Assessing service levels

When respondents assess the level of service offered by a publisher or the helpfulness of the review process for submitted articles, we can assume that opinions are based on their own experiences or those of close colleagues. This is probably why the 'don't know' percentages are higher in Table 4 than in Table 3.

Table 4: Assessments of service level and review process (% of responding authors)

Service level and review process	AIC	BRI	CI	CME	ECAM	IJPM	JCEM
Publisher service level							
Don't know	*67*	*67*	*77*	*33*	*59*	*53*	*41*
For those who know the journal: High, or almost high (4–5 on the 5-degree scale)	52	60	38	79	42	61	57
Helpfulness of review process							
Don't know	*67*	*65*	*78*	*32*	*57*	*48*	*39*
For those who know: High, or almost high (4–5 on the 5-degree scale)	57	57	35	77	48	57	74

Submission rejection risk

According to Table 5, the respondent estimates of the average submission rejection risks were typically concentrated in the 25–50% and 50–75% ranges. A few observations can be made about the results. *Construction Innovation* was deemed to be the easiest journal to get published in with a clear dominance of answers in the <25% and 25–50% ranges. *Building Research and Information* attracted the widest spread of estimates, with 16% of the respondents guessing for less than 25%, while at the other end of the range 11% guessing at a rejection rate in excess of 90%. Guesses for *Construction Management and Economics* were highly concentrated in the 50–75% range. The explanation for this more narrow range might be that CME has made available on its web pages annual statistics for submissions and published articles; it is thus likely that many authors know that the average CME rejection rate has been around 50% for a number of years.

Table 5: Perceived risk of rejection (% of responding authors)

Submission rejection risk	AIC	BRI	CI	CME	ECAM	IJPM	JCEM
Don't know [% of authors]	*73*	*71*	*79*	*48*	*62*	*54*	*48*
For those who think they know:							
<25%	17	16	44	8	16	20	6
25–50%	43	21	30	21	49	33	32
50–75%	29	29	19	57	27	35	37
75–90%	11	24	7	14	6	8	18
>90%	0	10	0	0	2	3	7

Although there are no reliable statistics for scientific journals in general it is worth mentioning that the Director of Strategy of Elsevier, the biggest scientific publisher, recently revealed (Fowler 2007) that they process more than 500 000 submissions per year resulting in more than 200 000 published articles, which amounts to an overall rejection rate of about 60%.

Posting copies of manuscripts or articles openly on the web

There are currently strong demands for changes in the scholarly publishing systems to better take into account the opportunities offered by the Internet. Open Access, as this alternative to the traditional dissemination model is termed, can be achieved in two ways. The first route is that journals themselves start posting the articles totally openly on the web, this being run as an open source like operation with no budgets, or journals recoup their costs by other means than subscriptions, for instance by publishing charges. The *Lean Construction Journal* and the *Journal of Information Technology in Construction* (ITcon) are examples of the former type. The use of author charges is practised in particular by two biomedical publishers, BioMedCentral and Public Library of Science.

The second route is that authors publish in the same journals as usual, but themselves post copies of their manuscripts prior to or after peer review on their own web pages, in the institutional repositories of their universities or in subject-based repositories such as the ITC Digital Library (http://itc.scix.net/) for construction informatics. Contrary to a widespread belief among scientists many publishers allow this practice in their copyright agreements with authors. The Sherpa/Romeo database (http://www.sherpa.ac.uk/romeo.php) contains information about the policies of all major publishers, and according to it a vast majority of journals allow posting of even the final corrected manuscript after peer review but before final publishers' copyediting and layout.

We asked the authors in our survey if they have put up copies of their manuscripts or final versions of conference papers or journal papers on the web. Very few had done so. The most popular location for manuscripts was the author's own home pages where 18% had posted at least one manuscript, and for final publications, the institutional repository of the author, where again 18% had posted at least one publication. It appears that 3% had posted all their manuscripts and also 3% all their final publications openly on the web. These results are in line with broader studies of authorial behaviour in general (JISC 2004), which indicate that open access copies are available for only about 5–10% of all journal articles.

CONCLUSIONS

Our survey results show that researchers who publish scientific articles in the field of construction management do not differ markedly from academic authors in general. They do read slightly fewer articles, and they are little concerned with journal impact factors. Much like in other fields they enjoy being read by a narrow circle of peers. Scientific publishing fills an important role as a reasonably neutral and global system of talent assessment that influences decisions on promotion and tenure in many university cultures. It is possible to detect profiles of CM journals that could be used as a broader base for benchmarking from the viewpoint of authors. This should also be helpful for journal publishers and editors who wish to make their journals more attractive as outlets for research in the field.

From our analysis a cluster of three core journals emerges (CME, IJPM and JCEM). These three are regularly followed by at least half the respondents, which also could indicate that they have personal subscriptions or institutionally paid access to them. Unfortunately only one of these (JCEM) is indexed in the Science Citations Index, which makes citations-based comparisons difficult. The other four journals receive lower scores on readership as well as on some of the other perceived characteristics.

At present, construction management authors rely on open access publishing to about the same extent as authors in other academic fields. The slow convergence of traditional paper-based publishing and digital publishing leads to new patterns and business models.

Although the response rate is high for this type of email survey, bias in favour of email readers is probably something that has to be kept in mind when interpreting the results. Thus our responses might overstate the proportion of authors who actually post their texts on the web.

ACKNOWLEDGEMENTS

We would like to thank all participants in the web-based survey, some of whom also separately provided encouragement by emailing us. We would also in particular like to thank Patrik Welling, who helped in setting up the technical part of the survey.

REFERENCES

Adeli, H (2007) Measuring research journals (editorial). *Computer-Aided Civil and Infrastructure Engineering*, **22**(1), 1–5.

Betts, M and Lansley, P (1993) *Construction Management and Economics*: a review of the first ten years. *Construction Management and Economics*, **11**(4), 221–45.

Betts, M and Lansley, P (1995) *International Journal of Project Management*: a review of the first ten years. *International Journal of Project Management*, **13**(4), 207–17.

Björk, B-C and Turk, Ž (2000) How scientists retrieve publications: an empirical study of how the Internet is overtaking paper media. *Journal of Electronic Publishing*, **6**(2), available at http://www.press.umich.edu/jep/06-02/bjork.html.

Björk, B-C, Turk, Ž and Holmström, J (2005) The scholarly journal re-engineered: a case study of an open access journal in construction it. *Electronic Journal of Information Technology in Construction, ITcon*, **10**, 349–71, available at http://www.itcon.org/.

Björk, B-C, Turk, Ž and Holmström, J (2006) Benchmarking scientific journals from the submitting author's viewpoint**.** *Learned Publishing*, **19**(2), 147–55.

Chau, K W (1997) The ranking of construction management journals. *Construction Management and Economics*, **15**(4), 387–98.

Fowler, N (2007) Powerpoint presentation at the conference Scientific Publishing in the European Research Area – Access, Dissemination and Preservation in the Digital Age, Brussels, 15–16 February 2007, European Commission.

JISC (2004) JISC/OSI Journal authors survey report, prepared by Key Perspectives, available at http://www.jisc.ac.uk/uploaded_documents/ACF655.pdf.

Pietroforte, R and Stefani, T P (2004) *ASCE Journal of Construction Engineering and Management*: review of the years 1983–2000. *Journal of Construction Engineering and Management*, **130**(3), 440–8.

Tenopir, C and King, D W (2000) *Towards electronic journals realities for scientists, librarians, and publishers*. Washington, DC: Special Libraries Association.

WHO READS *CONSTRUCTION MANAGEMENT AND ECONOMICS* AND WHY?

David Seymour[1]

School of Engineering, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

Taking the latest issue (at time of writing) of *CME*, the 23 articles it contains are examined. It is proposed that 11 of them can usefully be thought of as narratives that describe a context in such a way as to instruct the reader on how the particulars reported in the study are to be understood. A second set of papers describes tools, techniques or methods designed to contribute directly to industry practice. A sample of the papers are discussed in detail with reference to the questions: to whom is the research addressed with what purpose, how success in achieving that purpose is judged and what other criteria for success might be considered. The conclusion is that the research reported is primarily read by other researchers. Three reasons are offered for why they are read: first, in the expectation that the research tells of innovations and developments that might be applied in practice, 'practice' understood to include the concerns of site operatives through to national governments; second, in the expectation simply of learning things that were not known before about the construction industry worldwide; and third, and most importantly, because readers look for stories that make more sense than the ones they already know, concerning themes of which they are already aware and to which they wish to contribute. On the assumption that the conclusion is correct, suggestions are made as to: (i) ways of ensuring that topics which are researched address practitioner interests and concerns; and (ii) ways of ensuring that they *are* addressed are made an intrinsic part of the research process.

Keywords: communication, narrative, research, practice.

INTRODUCTION

The title of this paper expresses questions to which I don't know the answer. I have my guesses, which I can best begin to explain by citing Stephen Holmes' review of Francis Fukuyama's new book (Holmes 2006: 13). This book is a follow-up to his story – set out in 'The end of history and the last man' – which was that with the fall of communism we find ourselves in a capitalist paradise. The events of 9/11 have given him cause to think again, hence the new book and a new story.

"The question is: [writes Holmes] does Fukuyama tell us anything we don't already know? Can he explain how 'the irresponsible exercise of American power' became 'one of the chief problems of contemporary politics'? Can he help us understand how 'so experienced a foreign policy team' could make 'such elementary blunders'? Can he indeed tell us why the administration decided to do what he and his former allies had encouraged them to do […]?"

I highlight the words: "tell us", "explain" and "help us understand" "what […] to do" and will draw some parallels with construction management research. "Tell us" implies information about a new method or technique; that a piece of research has

[1] d.e.seymour@bham.ac.uk

found out something that was not known before; that it provides factual information about a given state of affairs; remedies mere impressions and guesses or claims to show that what was thought to be known is wrong. “Explain” implies connectedness; associating things and events, perhaps causally, not noticed before or challenging received explanations. “Help us understand” implies both of the above but more modestly providing some kind of narrative, a story that makes sense; pulls together previously (for us) disparate information and impressions. All of them, either explicitly or implicitly address the question: so what do we do? This last, in Fukuyama’s case, a matter of encouraging the administration to do things for which he is now bringing them to book.

I began with the reference to Fukuyama because he has provided a dramatic instance of the apparent need people have for some kind of narrative, a story that sets all in order, the better if it gives grounds for optimism, hope that positive change is feasible. It seems to me that most of the contributions to *CME* have this objective. With the view to testing this hunch and with Holmes’ questions in mind, I reviewed the 23 contributions to the April–June 2006 issue of the journal (the most recent to hand), assuming that it would be adequately representative of what is on offer.

Ten of them, as I will try to show in Section 2, aim to tell a story. Though not as weighty as the global politics addressed by Fukuyama, they have a similar purpose: to describe a state of affairs from a claimed position of academic detachment. Usually, the authors attempt to justify their claim to objectivity in a methodology section. Sometimes they say what their purposes are, sometimes who the story is intended for, why they should listen and what the moral of the story is. I will consider each of them in turn. In Section 3, I will consider seven further stories whose purpose is different, namely, to describe a tool, method or technique designed to improve financial and contract management practices that are claimed to be useful to industry practitioners; then another five that are about tools or methods designed to improve performance on a range of important and necessary tasks. In Section 4, I consider the final paper, which provides both the description of a tool and a story with very interesting results. In the concluding section I will suggest ways of ensuring that topics which are researched address practitioner interests and concerns, and ways of confirming that they *are* addressed are made an intrinsic part of the research process.

STORIES AND CONTEXTS

I call this section ‘Stories and Contexts’ because the main purpose of the papers reviewed here is to provide some kind of overview, to characterize a context in such a way as to have us understand particular instances (phenomena and events) in a particular way. There has long been an interest in stories as cultural products since they have much to tell us about social organization. For example, ‘moral tales’, are used to inculcate the values and norms of a given society. More subtly, an action plan, a strategy statement and other artefacts can also be seen as a kind of story, detailing, for example, what has to be done. However, fairly recently the fact that *reporting research* into social organization can itself be seen as story telling has also become of interest. Challenging the representationalist conception of language (that it can be used to describe what is really ‘out there’), the ontological status of concepts like ‘organization’ or ‘culture’ become problematic. Thus, by what *cultural processes* do such concepts acquire apparently concrete status “as already constituted entit[ies]?” (Chia 1996: 583). The position adopted in this paper is that in highlighting these *cultural processes* by which words acquire the meaning they do, it becomes apparent that there are (for our purposes here) two distinct milieus in which the processes occur: construction industry organizational practice and the *reporting* of that practice by academic researchers.

In the former, there are stories that have a clear practical purpose, enabling people to communicate intentions, understand what other people are doing, learn what the rules are, what happens to deviants and so on, making possible shared, or at least negotiated, definitions of the situation and thus orderly social interaction.

The milieus for *reporting* industry practice are journals like *CME*, academic conferences and sometimes industry workshops or seminars where practitioners are addressed. All of these are settings subject to their own rules and conventions. The questions I raise are: how does what goes on in these milieus relate to each other, and how do the stories that are produced within them relate to each other? Putting it slightly differently, how do the ways researchers contextualize what they report relate to the contexts that practitioners take for granted as existing? If, following the line of reasoning offered by Chia and others, they are all cultural constructions, simply different versions or stories, what then? This is especially important when, as we will see in some of the papers considered, researchers *contradict* practitioners, claiming to know more or better than they do.

To begin with Caven, she tells a story about the careers of women in architecture based on interviews with a sample of them, some of whom are allowed to speak for themselves for illustrative purposes. Its aim is generally to persuade readers of the truth of the story she tells and also to promote the interests of women in the job market. Citing several commentators who have asserted that "the construction industry has historically not appealed to women as it is perceived as being physically demanding, combative and male dominated" (p. 457 – all page references given, unless indication to the contrary, refer to *Construction Management and Economics*, **24**(4–6), 2006), she gives some statistics to support their story and proceeds to use it as a backdrop or context for the story she is about to tell. There is nothing wrong in any of this. What I am highlighting is the fact that such a context is offered as real, in the sense that since a number of experts have described it as such and in the absence of accounts to the contrary, it may be accepted as a true account of the way things really are. This is not to say I don't believe it. In fact, with respect to the UK with which I have some experience, I do. But of course, the description is a cultural construct, a story – no more nor less – reflecting the concerns, interests, understandings and meanings of the person who provides it in a setting or milieu in which s/he has reason to provide it.

Styhre and Josephson tell a story about middle managers on construction sites that is intended to challenge the received story. They too allow people to speak for themselves. They advocate, presumably to those in the industry who can remedy the situation, a more positive image of these managers. The reason they are telling the story of what they have found out, which (again) I have no reason for doubting, has explicit reference to other stories i.e. those that proclaim that middle managers are redundant. It is these which provide the context for Styhre and Josephson's story.

A story about partnering is told by Phua. She rejects the alleged cynicism of Bresnen and Marshall (p. 615) arguing that theirs and most other accounts are based on restricted case studies and that what is required is "large scale cross-sectional studies to examine the relationship between [partnering's] ubiquity and corresponding impacts" (p. 615), i.e. the 'big picture' or a fuller story. She reports a study designed to provide it. With findings from a postal questionnaire survey, her conclusions are not in fact much different from Bresnen and Marshall's – that 'institutional norms', for which I read 'existing culture(s)' have a conservative effect on take-up. She is also at one with them in trying to operationalize 'industry norms' and 'partnering', treating them as finite entities to establish causal relationships between them, ignoring Chia's point that the ontological status of these terms is such that they cannot refer to finite entities. She differs, however, in that she departs entirely from actual decision-making practice which Bresnen and Marshall try to keep in sight, relying on the statistical manipulation of data derived from a fixed-choice questionnaire survey, stimulating extreme doubt about its ability to reflect the variety and complexity of the processes to which these words (i.e. 'industry norms' and 'partnering') refer. Thus, I submit, this story can have no special status as being truer or better than another. It is a matter of believe it if you want to; be persuaded by the evidence offered in support of it, but wait for the next study which, contrary to what Phua has found, may claim to show that it is "decisions grounded in financial inducements" (p. 622), which is the main determinant and not 'institutional norms. How one actually distinguishes 'industry norms' and 'decisions grounded in financial inducements' is another question.

The story by Kale and Arditi is about the diffusion of ISO 9000 to Turkey. It uses the theoretical framework provided in the Population Ecology approach of DiMaggio and Powell (1983) and others, which posits an ever-expanding set of rationalized organizational models and ideologies, such as ISO 9000, which organizations throughout the globe variously try to imitate and incorporate. Though DiMaggio's and Powell's approach acknowledges that these attempts may be merely ritualistic or used opportunistically with little practical outcome relative to overt objectives, nonetheless their approach precisely formalizes out of view the intricate processes involved in particular settings where management systems like ISO 9000 are introduced.

We meet the same problem that we saw with Phua, trying clearly to identify a variable that impacts on other variables. Thus, Kale and Arditi assume that there is a finite set of practices found in economically advanced countries that constitute the application of ISO 9000 (and note, not the prescriptions contained in the ISO 9000 documentation itself) and it is this (thing) that is being imitated. However, as with partnering, there are a multitude of practices which pass as 'being Quality Assured' despite the certification procedures that ISO 9000 imposes. So, what exactly is it that imitating firms are supposed to be imitating? Certainly not the ideational construct identified as ISO 9000 by Kale and Arditi for the purposes of their model, rather, a range of practices that can only be found out by a close study of those practices in the settings where they are employed. Second, suppose they are imitating something, why are they imitating it? Kale and Arditi say that there are three possible reasons: (i) internal, i.e. in pursuit of rational efficiency and because other firms are doing it; (ii) external, i.e. influences from e.g. government regulation or client requirements; (iii) mixed, i.e. a combination of both the above. The first comment is that Kale and Arditi's conclusions, i.e. the story told about firms in Turkey as to what they are doing and why, is that by restricting the kinds of reasons on offer it ignores others that might be at work (the same problem noted with Phua above). Second, it is ethnocentric. It supplies rationales that might be expected in a Western, developed economy, again failing to disclose rationales that might be present in Turkey. Third, it ignores the processes through which action in the name of ISO 9000 is understood, interpreted, challenged, validated and evolves in Turkey or anywhere else.

An anthropological study of a company in Sudan by Rottenburg (1995) directly addresses Population Ecology theory and shows its distortive effects. He argues that its use confuses efficiency with legitimacy since they are so thoroughly conflated in western industrial societies. However, he argues, reminding us of Max Weber's warning on precisely this point, that even in the West, the public justification for an organizational format may be efficiency, but, that format is just as likely to be adopted because it legitimates what goes on "behind the façade" whether efficient or not. In, what Rottenburg calls, "peripheral countries" the justification is more likely to be the latter whilst behind the protective façade any number of practices grounded in other legitimating frameworks may be in operation, obligations to religion, kinship and friendship, for example, which are selectively invoked as the situation requires. Thus, people in a given setting have their own stories about what is going on and it is these stories that inform what they actually do. It is these stories that need to be listened to and understood if we are to find out what is going on the better to understand the intricate dynamics of organizational change and technology transfer. Thus, he presents a complex picture where members of the Sudanese company tactically invoke competing legitimacy discourses, some provided locally and some from a global repertoire, depending on the particular setting and their purposes in it. All this is lost by imposing the explanatory model that Kale and Arditi use.

Liu and Fang tell a story about leaders on Chinese construction projects, apparently not having consulted any of them and this is the point. By aggregating information provided via a questionnaire survey, the authors assume that it is possible to access generic forces at work and that by doing so they can find out something about the dynamics of leadership that any given leader does not know. I suppose Liu and Fang might concede that any given leader may arrive at the same conclusions as they do, conclusions that are verifiably correct through their scientific study. They confess that a lot more work needs to be done to test the validity of their finding but imply that it can be done (p. 505). I suspect, however, that no matter how much more is done, it will just increase the complications and the need for more caveats. In short, their truth claim as to the dynamics of leadership cannot be settled by appealing to 'facts' characterized within a discourse, which provides the context for their study. This is so because it is not the discourse through which the phenomenon itself (i.e. leadership) is constituted in the everyday reality of construction projects. That is, we recognize leadership in the first place in the everyday world in which it is enacted. Thus, though Liu and Fang may characterize leadership within a particular discourse that is different from the way it is characterized in the everyday discourse of a construction site, there is no difficulty "in agreeing that there are persons recognizable as [leaders]. It is this agreement – agreement as to the fundamental ordered existence of the phenomenon independent of it having been addressed by *some* method of enquiry – that [Liu and Fang and people on construction sites] are mutually orientated to a common factual domain" (Zimmerman and Pollner 1971: 81).

In referencing Foucault, they invite another comment that bears on the same matter. Foucault advises that power, which is central to Liu and Fang's theory of leadership, is not to be thought of as a force that can be stood back from and observed as they seem to assume. It exists in the very language we use to characterize human experience. In modern prisons, he suggests (Foucault 1975), disciplining is not experienced as repression but as the necessary condition of the productive work in which prisoners are required to engage and which they accept. Institutional power is so complete that they repress themselves. One need not accept the full implications of what Foucault is saying, i.e. that prisoners are duped into accepting a discourse such that they see repression as discipline. It might be that they accede to the use of the discourse for tactical reasons of their own (like Ronnie Barker in Porridge!) knowing perfectly well what they are required to think. However, what Foucault powerfully highlights is that we conduct our lives in terms of versions of what reality consists of. Whether some versions or discourses *succeed* in excluding or marginalizing others is an empirical question. It would seem to follow, therefore, that if we are to understand leadership in construction we do well to attend to the way people characterize it and its effects *there*. A fixed-choice questionnaire schedule pre-empts our understanding of the way stories of leadership together with a range of other communicative devices are used to confirm the existence of leaders, how you recognize them as leaders and so on. Following Foucault, the discourse that Liu and Fang use to have us understand what leadership 'really' consists in, could be seen as an attempt to assert the power of researchers over practitioners! I return to this point later.

Ramsran and Hosein's story about Trinidad and Tobago is simply intended to inform, presenting findings from various statistical sources, pointing out the public policy implications which they see. Also using various statistical sources, Duncan, Phillips and Prus relate a story about contractors' response to the Government Fair Wage Policy in British Columbia. This paper also seems intended to inform and thereby influence public policy. Sources where further information can be found are usefully given. Thus, both assume familiarity with a common discourse as between providers of the story and those who read it. Readers are invited to take at face value the information provided. If we wish to, we may query their sources, how the statistics were generated and look for a different story – take it or leave it. The assumed context is that constructed by the kinds of information with which we are all familiar, global statistical accounts of this or that phenomenon.

Song, Liu and Langston's paper similarly concerns the provision of a global account, this time of the "construction sector" (p. 579). However, they seem equally divided between recommending the use of an economics technique and telling the story of what its application to construction reveals. Thus, the paper might also be considered under the heading of a tool whose usefulness to practitioners is demonstrated by what it tells us about the construction sector that we didn't know before.

Using data from company web sites and annual reports, Chang, Chou and Wang's story concerns corporate governance of UK construction companies. They are found to compare badly with 'top companies'. While it is never actually stated, the moral of the story seems to be that construction 'should do better' because "'it helps investors exercise their voting rights, raise managerial consciousness [pressurize] managers to fulfil their fiduciary duties" (p. 653). It is not made clear whether that is the purpose nor whom it is addressed to. Presumably, like the previous paper, it is thought to be of interest to anybody who has a use for the information it provides.

Johnson, Lizarralde and Davidson, with reference to two case studies and using a 'systems approach' (p. 369), tell the story about what happened regarding the provision of temporary housing following natural disasters and what can be learnt from them. Emphasizing the importance of organization design, the paper is addressed to people for whom such learning would be relevant. This paper also might be thought of as the recommendation of a tool – 'the systems approach'. However, what distinguishes it from Stewart and Stephens' (considered below) is that the story is not about how the tool was used but how it might have been used in the two cases considered. The context of the paper is the variously reported inadequacies of dealing with the aftermaths of natural disasters.

I have argued that all these stories should be seen as attempts to persuade or intervene and that the relationship with the intended ‘persuadee’ and the warrant for the attempt should be made clear. In all cases, one just submits to being informed or takes them with a pinch of salt depending how one is disposed. However, I suggest that in all cases, one is implicitly invited to test the truth of what is being told against some anonymous set of abstract criteria supposed to reside with some adjudicating body, presumably the community of construction management researchers, rather than the people about whom the various stories are told.

TOOLS, METHODS AND TECHNIQUES

Eight contributions are about methods, techniques and tools designed to improve financial and contract management practices. In all cases, the form of the research is similar. Justification for a new or better tool, technique or method is given. What it consists of and how it was developed are described. In some instances, this involved the collaboration of an industry partner. In others, it was based on data gathered from questionnaire surveys. An example of the former is Tang, Wong Leung and Lam’s tool for making loan decisions. It is not clear, but the study seems to have been a form of action research. Thus, it was simply taken for granted that it would be useful to develop a more reliable tool. Use of the tool is said to have been a success and that with appropriate adjustments it would have generic application. Cheung and Skitmore have developed a tool to help forecasters develop and evaluate their own cost models. This, they say, is “likely to be well received in practice” (p. 401). Wong and Hui identify risk factors that might affect tender price results that, they say, will be beneficial to employers and contractors. Thomas, Kalidindi and Ganesh’s risk probability and impact assessment framework is claimed to “provide insight into the various factors influencing events and their inter-relationships” (p. 420). Papers by Huang and Chou, Zhang and Yang, Yiu and Tam, and Cheah and Liu follow similar formats.

These are all interventions designed to influence and contribute to an ameliorization of industry practice, and are to be welcomed insofar as they do. However, I think it would be useful to know more about the way these products came to market and how, in addition to describing the product, the development process was managed. This might give genuine insight into the relationship between researchers and practitioners that we seem to know so little about. Recognizing space limitations in the journal, perhaps a brief product description and applications should be given and interested parties be referred to a website where more detailed information is available. This would serve the useful purpose of helping to answer the questions addressed in the title of this paper.

Turning to methods having other applications, Hyari and El-Rayes report on how to design effective lighting systems for road projects; Best and Langston on alternative methods for comparing construction performance cross-nationally; Hartmann on detecting factors that would influence the implementation of an innovative idea. Again, these are to be placed in the ‘take it or leave it’ category. The contexts that they assume in writing these articles may (or may not) be recognized and seen as relevant to the concerns of practitioners and acted upon.

Soetanto, Dainty, Glass and Price advise on how to improve group decision making processes, Navon and Berkovich on a materials management and control system. The former is intended to “help the professional disciplines in particular to improve service to their clients” (p. 612). Further research is advised to find out if it does or not. The latter assert that their system has been tested in the field with positive results and that further testing is under way.

While there is some attempt to specify whom recommendations are aimed at (e.g. Hartmann “relevant to researchers and practitioners”), there is little sense that these studies are rooted in the realities of the construction industry, what practitioners might have to say about them, how what is recommended relates to current practice, what problems there might be in implementation and so on. Regarding these issues, most of them seem to offer some under-examined variant of ‘it’s a cultural thing’. That is, the prime interest seems to be in some abstracted vision of construction practice where solutions to the problems experienced there can be solved ‘in principle’ by those at a salutary distance from them.

The final paper examined here, that by Stewart and Spencer, to an admirable extent is exempted from the preceding comment. This is achieved in an interesting way. It is explicitly an intervention and both describes a tool, six-sigma, and tells a story of its application in a case study. It is firmly rooted in on-site experience. The story has two objectives to “describe the application of the six-sigma method on a construction project’ and to evaluate its effectiveness” (p. 342). (The comments on Stewart and Spencer’s paper are influenced by an as yet unpublished analysis by John Rooke, which I have been privileged to read, where he points out the relevance of the Unique Adequacy criterion.)

The authors succeed in documenting how the method is used, how it figures in the on-site discourse. Thus, “firstly, the decisions made and their outcomes for two PIP’s [Project Improvement Projects] were recorded under the five stages of six-sigma philosophy”. For example, they show what went on in the constructability workshop, which was attended by the relevant construction personnel and “the improvement team” (p. 344). Six of the people involved were then interviewed as to their perceptions of the application of six-sigma and other TQM techniques. Apart from, presumably conducting the interviews it is not clear how actively involved the researchers were in the application.

Their story is clearly about what happened, the context being the industry-wide discussion of the practices that are intended to improve quality and efficiency. However, by virtue of the fact that it documents the use of a method germane to that setting, it attends to a *story* which is actively used in the setting, that story being – “do the following things and this is what happens”. That is, they show how the method (six-sigma) that participants in the setting used figures in organizing the social processes that occurred in that setting. Thus, the authors do not *import* a theory and vocabulary with which to tell their story, as do the other stories considered above. Their story, in the telling, displays a discourse used in that setting.

Nonetheless, finally they do implicitly abandon this genuinely objective and non-judgemental stance. Thus, they dismiss out of hand some of the observations of site members elicited during interviews. The respondents’ view was that “six-sigma mainly improved efficiency”. They comment that this “a common misconception about the concept of ‘quality’ and its relationship to the whole production process” (p. 346). In doing this, they address themselves to a wider context as understood by some wider community of which they see themselves part. This membership distinguishes them from those on site. It would be useful to know if their observation on this matter was discussed with site personnel serving to illuminate the relationship between academic and practitioner discourses, which, the present paper has argued, is routinely ignored.

CONCLUSIONS

My guess, then, about ‘who reads *CME* and why?’ is that the research reported in it is primarily read by other researchers. They may well pass on what they find out to students *en route* to becoming practitioners or to active practitioners with whom they have dealings. They may well be wholly or in part practitioners themselves. However, the more interesting question is why? Apart from just finding out what’s new, I think there are three reasons: first, the expectation that the research tells of innovations and developments that *might* be applied in practice, ‘practice’ understood to include the concerns of site operatives through to national governments; second, in the expectation simply of learning things that they didn’t know before, about, say, the construction industry in Trinidad and Tobago; third, and I think most importantly, they look for stories that make more sense than the ones they already know about themes they are already aware of and to which they wish to contribute better understanding. (I take it as read that there is a fourth reason for reading the Journal; that its content needs to be addressed by academics wishing to publish themselves and that there is pressure on them to do. To have taken up this issue would have raised many interesting questions about the institutional relations between the academic and construction industries. As important as they are, it was not my purpose to discuss them.)

If my guess is right, it is the assumed nature of this contribution that seems to be important. I began with the idea of the big picture that provides a context for understanding; a story that seems to offer a coherent account of why the social world is as it is. Such stories seem to get below the confusion of what goes on to provide an account that makes sense of it all. The contributions considered here as stories look to contribute to telling or retelling a story, adding to it, modifying or challenging it, confirming or disconfirming this or that feature of it. I have suggested that they be thought of as interventions, looking to influence what practitioners in the industry do and how they think. This is even more explicit in contributions regarding tools, methods and techniques. It is taken for granted in all cases that the main beneficiaries are industry practitioners, though in most cases I see little concrete evidence of this. Other beneficiaries are sometimes acknowledged; other researchers who are assumed to feed back directly into practice in ways noted in the preceding paragraph. But I think the dominant assumption is that research is ‘its own thing’, what Alfred Schutz calls “a finite province of meaning” with its own ways of conceptualizing issues, “its own cognitive style”, “its own specific accent of reality” (Schutz 1972: 232). Such reports that are produced within it are for others who share it, not for those whom the reports are allegedly about – construction practitioners. The latter’s frame of reference or their context is “the paramount reality” (Schutz 1972: 232) of the everyday world of construction. Thus, for example Stewart and Stephens, as noted above, participate in this everyday world in the application of six-sigma but then withdraw from it into the finite province of meaning shared by other researchers. In turn, they presume that from within it come reports that practitioners, who do not share it, should listen to on account of their greater accuracy, lack of bias and so on. In other words, Stewart and

Stephens shift from participating in a setting in which different viewpoints might be exchanged, to commenting on the setting from a position of assumed superior knowledge. In effect, they enter into discussion with a community of researchers who licence themselves to make such comments.

This is not to say that researchers may not know something that practitioners don't. The point is they need to communicate it; enter into a dialogue with those to whom this knowledge is supposed to be of value in the paramount reality of the everyday world. For this reason, and re-asserting my contention that all research in construction management is tacitly intervention of some kind, the criteria for judging its worth is to be found in the setting where research is actually done, taking into account the reasons for doing it. This implies that outcomes, the 'fitness for purpose' of what is found out, be given equal weight to justifying truth claims. Action research provides such criteria (e.g. Greenwood and Levin 1998; Bray *et al*. 2000), which are based on the assumption that such research is a collaboration between researchers and researched in the real world where, only there, can be found evidence as to its truth and usefulness.

REFERENCES

Bray, J N, Lee, J, Smith, L L and Yorks, L (2000) *Collaborative Inquiry in Practice.* Thousand Oaks, CA: Sage.

Chia, R (1996) The problem of reflexivity in organizational research: Towards a postmodern science of organization. *Organizations,* **3**, 31–59.

DiMaggio, P J and Powell, W W (1983) The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, **48**, 147–60.

Foucault, M (1975) *Discipline and Punish; The Birth of the Prison*, trans. Alan Sheridan, 1977. London: Allen Lane.

Greenwood, D J and Levin, M (1998) *Introduction to Action Research: Social Research for Social Change*. Thousand Oaks, CA: Sage.

Holmes, S (2006) After the Neo-Cons; America at the crossroads. *London Review of Books*, **28**(19).

Rottenburg, R (1995) When organizations travel: on inter-cultural translation. *In:* B Czarniawska and G Sevon (Eds.) *Translating organizational change*. New York: Walter de Gruyter.

Schutz, A (1972) *The Phenomenology of the social world*. London: Heinemann.

Zimmerman, D and Pollner, M (1971) The everyday world as a phenomenon. *In:* J Douglas (Ed.) *Understanding Everyday Life*. London: Routledge.

A REVIEW OF THE ABSTRACTS OF *CONSTRUCTION MANAGEMENT AND ECONOMICS*, 1983–2006

Roberto Pietroforte,[1] Nicola Costantino,[2] Marco Falagario[2] and Jonathan S. Gould[3]

[1]*Worcester Polytechnic Institute, 100 Institute R., Worcester, MA 01609, USA*
[2]*Politecnico di Bari, DIMEG, via Japigia 182, 70126 Bari, Italy*
[3]*Vanasse Hangen Brustlin Inc., Watertown, 101 Walnut S., MA 02471, USA*

Construction management (CM) is a relatively new discipline that has been expanding its domain of knowledge over the years. The presented study aims at tracing such an evolution by analysing the content of a leading academic journal, *Construction Management and Economics* (CME), namely its abstracts and keywords over a 24-year period, from 1983 to 2006. The content was classified according to a set of subjects and related topics, as well as the institutional sources of contribution. CM, as described in CME, is still an evolving body of knowledge with the inclusion of many new dimensions since 1983. Over the years contributors have shifted their interest towards the management of firms and away from that of projects. These two subjects are addressed more from the theoretical than the practical viewpoint.

Keywords: abstracts, bibliometric study, classification criteria, construction economics, construction management.

INTRODUCTION

This contribution was prompted by the upcoming 25th anniversary of *Construction Management and Economics*, a leading academic journal. The study aims at tracing the evolution of the journal over the years through the analysis of its content since its inception. Construction management (CM) encompasses a relatively new body of knowledge, if compared with the history of construction. Its first appearance in the USA was driven by a variety of challenges that afflicted the construction industry in the 1960s, namely the growing dissatisfaction of clients with the outcome of their investments and the traditional contracting system, the increasing design and construction complexity of projects and the weakening coordination capabilities of design professionals, to name some of the problems. In the late 1960s CM-related programmes started being offered by US civil engineering departments, followed by UK schools in Europe. Over the next 15 years CM's core of knowledge, originally drawn mainly from operations research, expanded and acquired its autonomous features and also emerged as a distinctive field of academic enquiry. The early 1980s, in fact, saw the establishment of the first peer-reviewed journals fully dedicated to the CM field. Since then CM has established itself as a research area that builds upon a long series of publications of scholarly work and debate. Academic journals within any specific discipline play a vital role because they are the primary means for communicating and exchanging research experience. Research or scholarly activities, at the same time, influence the teaching of a discipline and, over the years, the shaping

[1] roberto@wpi.edu

of educational programmes at large. As addressed by Betts and Lansley (1993), higher education provides the cultural capital and nourishment for the sustainability of professionalization and at the same time the addition of new knowledge, which influences the development of a profession, is likely to be traced in the academic journals. Typical examples are the arrays of periodicals that have sustained the architectural and structural engineering professions over the years. This type of reasoning, unfortunately, is more difficult to apply to CM in both professional and educational terms. In contrast to architectural and structural engineering practices, the responsibilities of CM activities are allocated differently around the world and, considering its interdisciplinary nature, it is difficult to consider CM as a distinctive discipline.

Furthermore the practice of CM can be considered more as a role than as a profession like that of architects or structural engineers. Depending on a given social, institutional and cultural context, in fact, CM assumes differing characteristics in terms of meaning, range of pertaining subjects and practice. In the USA CM is strongly associated with the American Society of Civil Engineers and its educational institutions. In this regard, academic programmes have a strong technical and technological content, but in practice most of the CM services are offered by construction firms and not professional engineering firms. In the UK and countries of the British Commonwealth, CM is associated with the professional institutions of surveying. In this regard, the domain of CM has a strong economic component (re: construction economics) that is a natural expression of the traditional cost advisory role played by professional surveyors. This profession is significantly involved with CM services, particularly project management, and has been the main development source of construction economics as a discipline distinct from ‘orthodox’ economics. In contrast, in Italy and other European countries CM is associated with the schools of industrial engineering and it has a weak affiliation with professional institutions. Similarly to the USA, most of the CM services are offered by construction firms.

In the past many academic journals have been the subject of bibliometric studies. In the case of CM, the content of journals concerned with construction-related research issues was investigated to provide a partial map of the discipline of construction management and project management (Betts and Lansley 1993 and 1995). More recently, the perspectives on construction research were addressed in terms of challenges of US academic communities (Chinowsky and Diekmann 2004). This paper contains additional results of an ongoing investigation aimed at assessing the past and possible future developments within the CM discipline as it is represented in the US and European academic journals (Pietroforte and Stefani 2004; Pietroforte and Aboullezz 2005). The study considers the papers published by *Construction Management and Economics* (CME) during a 24-year period, from 1983 to 2006. More than 1150 abstracts were analysed from two main perspectives: the type of subject (based on a 12-item list) and topic (from a list of more than 100) that makes up each subject.

The paper initially presents some essential information about the academic journal, including a brief historical introduction, its objectives and key statistical data. Afterwards the methodology for data gathering and the classification criteria, according to which the journal’s content was analysed, are addressed. The disciplinary (or institutional) sources of contributions are analysed. The last part of the paper outlines the breakdown of the papers’ focus in terms of CM and construction economics subjects as well as their component topics.

HISTORY AND STATISTICAL DATA OF THE JOURNAL

CME was founded in 1983 by the publishers E & FN Spon, in conjunction with the founding editor John Bennett at the University of Reading. Originally, one of the principal objectives of the journal was to foster links between industry and academia and address subjects that could 'bridge the boundaries between the traditional professions and craft of the construction industry' (Bennett 1983). In the UK, recently launched CM programmes were not supported by established theories or research methodologies and, at the same time, practitioners saw the journal as a forum for accelerating positive changes in the industry. Under Bennett's editorship the journal doubled in size, from three yearly issues in 1983 to six issues in 1991. In that period two journals merged into CME: *Construction Papers* (CIOB) and the *International Journal of Construction Management and Technology* in 1983 and 1987 respectively. Ranko Bon and Will Hughes took over the editorship of the journal in 1992, and Will Hughes became sole editor in 2003. Under his tenure the size of the journal has increased to 10 issues per year. Currently CME focuses on the management and economics of building and civil engineering as well as that of built facilities. For the purposes of this study and to facilitate the analysis of historical trends, the statistical data are organized into six four-year periods of observation that span 24 years, from 1983 to 2006. In the observed period, 1173 papers (including notes and comments) were published in the journal, with 2412 authorships, as shown in Table 1.

Table 1: Size and authorship of the journal over 1983–2006 period

	83–86	**87–90**	**91–94**	**95–98**	**99–2002**	**03–06**	**83–2006**
Number of issues	12	16	24	24	30	40	146
Number of papers	66	102	155	200	296	354	1173
Number of authors	101	175	286	391	654	805	2412
Authors per paper	1.53	1.72	1.85	1.96	2.21	2.27	2.06
Percentage of UK authors	0.55	0.39	0.49	0.47	0.30	0.29	0.36
Percentage of Commonwealth authors	0.16	0.23	0.25	0.29	0.44	0.37	0.34
Percentage of authors from the rest of the world	0.29	0.38	0.26	0.24	0.26	0.34	0.29

The number of papers published in CM increased by more than 500%, from 66 in the first observed period (1983–86) to 354 in the last period (2003–06). Such growth is also reflected in the number of authors (note that some authors published more than one paper in a given year) from 101 in the first period to 805 in the last period. The ratio of 'authors per paper' has also increased, from 1.53 to 2.27 over the entire observed period. This trend is probably driven more by the 'publish or perish' paradigm than by increased collaboration. As expected, the data show a decreasing UK authorship over the years, considering the tremendous growth of contributors and papers in the last 10 years of publication. The slack has been taken up by authors from Commonwealth countries, particularly from Hong Kong (15% of the total), Australia (10%) and Singapore (6%). In the category 'rest of the world' (29%), North American authors are the largest group (more than 40% of the authorship in this category). The breakdown of authorship by geographic area shows that CM draws 70% of contributors from countries that share similar social, institutional and educational systems (UK and Commonwealth). The relatively small share of contributors (17%) from countries other than the previous group and North America suggests that, even considering language barriers, CM as a field of inquiry and practice does not attract the same interest as in the Anglo-Saxon world.

GATHERING OF JOURNAL DATA AND CLASSIFICATION CRITERIA

The content of this paper builds upon a database that records the title of each paper, abstract, key words, author/s, their affiliation and country of origin. Data were drawn from the ARCOM database which is available on line. As stated above, one of the goals of the research was to classify and group the content of the papers according to subjects. To this purpose the following and previously developed classification framework (Pietroforte and Stefani 2004) was used:

1. Management of the firm
2. Construction planning and control
3. Time scheduling
4. Site and equipment management
5. Construction methods and materials
6. Human resources
7. Project management
8. Cost estimating and models
9. Project delivery systems
10. Contractual issues
11. Industry issues
12. Research and innovation issues

Successively the content of the abstracts and related keywords were classified according to a set of topics that describe each of the considered subjects. In this regard more than 100 topics were addressed. The order of the above-listed subjects reflects three broad ‘perspectives’ according to which the content was interpreted: the first six subjects focus on the operations and business of a construction-related firm, the following four subjects focus on the project planning, organizing and control by a client (or his/her representative), while the last two subjects focus on issues related to the construction industry at large including those related to construction economics. The CM discipline builds upon an array of knowledge domains from social sciences and engineering science, among others. Since its establishment by practitioners, there have been efforts by the academic community to systematize its knowledge, traditionally based on experience. These efforts encompass exploratory studies of construction phenomena, analytical constructs, modification/application of theories from other disciplines and applications of techniques (often drawn from operations research) to solving soft and hard construction process problems. The interdisciplinary nature of CM is reflected in Table 2 which shows the type of disciplinary sources or academic institutions of the 2412 considered authors. It should be noted that there have been changes in the title of schools and departments. The internationalization of the journal, in addition, suggests that different terminologies are used to describe construction-related programmes (e.g. industrial engineering) outside the Anglo-Saxon world. The resulting classification, consequently, aims at a loose identification of contributing disciplinary sources such as engineering, architecture, surveying, management and social sciences rather than presenting an accurate picture of the academic location of the CM field. Over the 1983–2006 period, contributors from engineering (civil, building and industrial engineering) appear to form the largest group (approximately 41%), followed by those from areas such as surveying (approximately 31%). Most of the increase in the group of consulting and construction firms is driven by government research agencies. Over the years CME has not attracted many contributions from practitioners. The sizeable number of contributors (approximately 7%) from institutions not directly affiliated with construction (i.e. economics, social sciences and business) suggests that CM and construction economics are recognized as a distinct field of enquiry by scholars from other established disciplines.

Table 2: Disciplinary origins of contributions

	83–86	87–90	91–94	95–98	99–2002	03–06	83–2006
Consulting, construction firms and government agencies	7	20	17	26	66	86	222
Architecture	2	11	11	25	82	48	179
Civil engineering	34	49	49	77	125	188	522
Building engineering	14	10	45	61	72	110	312
Industrial engineering	2	6	15	53	41	36	153
Building and surveying	35	63	106	97	196	243	740
Economics/social science/business	3	8	25	29	33	66	164
Others sources	5	10	17	22	37	29	120
Total	100	174	281	383	646	796	2412

EVOLUTION OF THE JOURNAL CONTENT

As stated earlier, one of the objectives of the study was to assess the content of the journal and its evolution over the years. Table 3 shows the counts of the classified subjects over the examined period.

Table 3: Classification of abstracts by subject (in percentage)

	Subjects	83–86	87–90	91–94	95–98	99–2002	03–06	83–2006	83–94	95–2006
1	Management of the firm	0,09	0,16	0,14	0,08	0,21	0,19	0,16	0,14	0,17
2	Construction planning and control	0,08	0,04	0,06	0,06	0,06	0,03	0,05	0,06	0,05
3	Time scheduling	0,03	0,04	0,02	0,05	0,03	0,03	0,03	0,03	0,03
4	Site and equipment management	0,05	0,04	0,03	0,05	0,05	0,05	0,04	0,03	0,05
5	Construction methods and materials	0,00	0,02	0,02	0,01	0,01	0,03	0,02	0,02	0,02
6	Human resources	0,03	0,11	0,07	0,07	0,05	0,08	0,07	0,07	0,07
7	Project management	0,11	0,07	0,11	0,06	0,09	0,09	0,09	0,10	0,08
8	Cost estimating and models	0,24	0,12	0,13	0,12	0,06	0,07	0,10	0,15	0,08
9	Project delivery systems	0,08	0,07	0,06	0,09	0,08	0,08	0,08	0,07	0,08
10	Contractual issues	0,05	0,05	0,05	0,07	0,04	0,03	0,05	0,05	0,04
11	Industry issues	0,23	0,23	0,23	0,23	0,28	0,26	0,25	0,23	0,26
12	Research and innovation	0,03	0,07	0,09	0,14	0,04	0,06	0,07	0,07	0,07

The frequency of subjects varies from a minimum of 2% (construction methods and materials) to a maximum of 25% (industry issues). The large size of this last subject is driven by topics such as construction economics, international construction and housing issues. More than 30% of the subjects pertain to a body of knowledge that is typically deployed with professional advisory services to clients (cost estimating, project management and project delivery systems) that are typical of professionally oriented firms. On the other hand, a relatively low number of subjects related to technology (subjects 4 and 5) has been observed. This pattern is not surprising since CME's mission does not strongly embrace technology issues. In the last 12 years, however, there has been an increasing interest in technology-related topics such as site equipment management, logistics and site related environmental issues, as shown by the trend of subject 4. This interest was probably spurred by several UK government reports advocating better productivity in the industry. Although productivity improvements are also achieved with more efficient technologies, nevertheless the number of papers pertaining to this subject (construction methods and materials) has remained relatively low. If the 1983–94 and 1995–2006 periods are compared, no significant changes are observed within the considered subjects, with the exception of cost estimating and models whose counts almost halved. This apparent stability actually hides many changes in the topics that make up each subject, as will be shown later in the paper. Some of these changes are shown in the 'perspective' dimensions or level of analysis that characterizes the published contributions, as shown in Table 4.

Table 4: Classification by perspective of the abstracts (in percentage)

Perspectives	**83–86**	**87–90**	**91–94**	**95–98**	**99–2002**	**03–06**	**83–06**	**83–94**	**95–2006**
Firm	0,27	0,40	0,34	0,31	0,41	0,41	0,37	0,34	0,38
Client	0,47	0,30	0,35	0,34	0,28	0,27	0,31	0,36	0,29
Industry	0,26	0,29	0,32	0,36	0,32	0,32	0,32	0,30	0,33

The overall count is almost equally distributed according to firm, client and industry level of analysis. A closer observation of the 1983–94 and 1995–2006 periods suggests that CME's contributors are moving away from addressing the management of projects (client's perspective) and towards the operations of firms and general issues of the construction industry. Past analysis of another related academic publication, ASCE *Journal of Construction Engineering and Management*, has shown an overwhelming interest in the operations of construction firms (more than 65% of cases) and significantly less emphasis on project or industry level of analysis, 19% and 15% respectively (Pietroforte and Stefani 2004). Most published contributions are by authors from civil engineering schools.

Table 5 shows the count of the topics that make up each subject. Because of space limitation, only topics with at least seven counts are recorded. New topics that appear in the 1995–2006 period are in italics. It should be noted that almost all listed topics show an increasing number of counts. This was expected considering that in 1995–2006 the number of papers increased by more than 250% if compared to that of the 1983–94 period.

Table 5: Classification of abstracts by topic

Topics	**83**	**95**	**83**
	94	**2006**	**2006**
1. Management of the firm			
Bidding activities and strategies	15	27	42
Business planning and strategy	12	24	36
Inter-firm relationships	0	31	31
Corporate programmes, e.g., TQM, JIT	0	17	17
Accounting & financial management	3	12	15
Corporate culture, organization structure	6	6	12
Management of information systems	4	8	12

Topics	**83**	**95**	**83**
	94	**2006**	**2006**
8. Cost estimating and models			
Cost modelling, cost data	9	15	24
Deterministic estimating techniques	8	10	18
Non-deterministic estimating techniques	5	11	16
Cost control, project cash flow	9	7	16
Life cycle costing	6	9	15
Time cost integrated considerations	3	10	13
Quantity surveying	7	3	10

Adoption of innovation	0	8	8
2. Construction planning and control			
Resources planning and allocation	4	9	13
Planning of construction, phasing	8	5	13
Production control systems, criteria	2	10	12
3. Time scheduling			
Non-deterministic time scheduling techniques	2	8	10
Time duration estimate, variability	1	7	8
4. Site and equipment management			
Equipment costing, selection and management	5	12	17
Material and component management, handling	3	6	9
Preservation of historic sites and buildings	2	6	8
Environmental contamination and management	0	7	7
5. Construction methods and materials			
Evaluation of methods and building parts	4	6	10
6. Human resources			
Safety issues and programmes, management	7	24	31
Management characteristics and style	7	14	21
Factors influencing productivity and performance	6	14	20
7. Project management			
Design and value management	5	18	23
Project environment and culture	1	11	12
Project planning and organization	12	11	23
Project quality planning and control	5	9	14
Project risk analysis and management	5	6	11

9. Project delivery systems			
Project delivery systems with private financing	1	20	21
Evaluation of capital investments	7	13	20
Project delivery systems and contracts	5	12	17
Selection and evaluation of contractors	2	12	14
Financial evaluation, failures	1	7	8
10. Contractual issues			
Claims and disputes, negotiation, resolution	7	19	26
Management of contractual clauses	3	10	13
Contractual clauses and risk allocation	5	7	12
11. Industry issues			
Foreign construction issues and practices	21	55	76
Economic studies	19	48	67
Housing issues	6	22	28
Roles and cooperation in the industry	8	16	24
Environmental issues in construction	0	21	21
Women and minorities in construction	1	17	18
Codes, standards and information systems	1	15	16
UK industry structure and performance	5	10	15
Industrial relations, workforce issues	5	8	13
12. Research and innovation			
Research methodologies and needs	5	31	36
Innovation and technology transfer issues	6	15	21
IT-based integration and communication	6	4	10
Construction automation and robotics	3	4	7

The following are the topics with the highest number of counts and growth:

- Bidding activities, business planning and strategies, inter-firm relationships, corporate programmes, accounting and financial management (subject 1)
- Resources allocation and production control systems (subject 2)
- Equipment costing selection and management (subject 4)
- Safety issues, productivity factors and management, characteristics of managers (subject 6)
- Project management and organization, design management, project quality issues (subject 7)
- Cost modelling and data, non-deterministic estimating and time/cost considerations (subject 8)

- Project delivery systems with private financing, e.g., BOT, evaluation of capital investments and contract and project delivery systems (subject 9)
- Claims and disputes resolution, and management of contractual clauses (subject 10)
- Non-UK construction issues, economic studies, housing, roles in the industry, environmental issues, and women and minorities in construction (subject 11)
- Research methodologies and debates, and innovation issues (subject 12)

There are other topics, not shown in Table 5, that did not appear in the 1983–94 years: constructability analysis, environmental management, selection of consultants and management of project cooperation. Without doubt the comparison of the topics addressed in the two observed periods suggests that the content of CME has indeed expanded and evolved. If the subjects encompassing the perspective ‘firm’ are considered, in the 1995–2006 years there has been a growing interest in management theories for corporate strategies and operations, and in techniques such as TQM and JIT, as well as cooperation among the firms involved in construction projects. These new dimensions have expanded the knowledge domain of business management that previously was mostly dominated by bidding activities and strategies. Furthermore the second observed period is characterized by a thrust towards understanding the behaviour and characteristics of human resources within construction-related organizations. The count of subjects with the ‘client’ perspective did not increase as much as those encompassing the perspectives of the ‘firm’ and ‘industry’. This pattern may suggest that the body of knowledge pertaining to project management did not evolve or expand much over the years. Quite the contrary, and particularly in the last observed period, new dimensions emerge with an increasing interest in professional services that enhance the quality of projects and the value of designs submitted to clients. Project management expands the range of its activities to include the consideration of new project delivery systems (particularly public projects with private financing) and the evaluation of related capital investments, beyond the traditional cost advice activities of the first period. At the same time the increasing number of contributions focusing on claims, disputes and their resolution, as well as on the management of contractual clauses in general, underlines the growing legal complexity of modern construction. The third perspective, ‘industry’, of contributions shows the relative largest number of emerging new topics, such as environmental issues, role of women and minorities in construction, and international standards, e.g. ISO. Established fields such as construction economics have continued to expand. The initial emphasis on microeconomic aspects (e.g. cost estimating and bidding) has been complemented by macroeconomics aspects focusing on the economic structure of the construction industry and its interplay with the rest of the economy. The growing number of international authors is reflected in the many studies pertaining to non-UK construction industries and practices. Lastly, the large number of contributions focusing on research methods and relative debate among academicians underlines the need for establishing theories in the CM field. Unfortunately, most of the observed debate is not complemented by studies that reflect practice research. Over the years, in fact, contributions to CME seem not to have developed ‘hand-in-hand with the leading edge of practice’, one of the original intents of the journal (Bennett 1983). Lastly, the paucity of contributions addressing IT applications should be noted. This pattern is puzzling considering the wide adoption of web-based integration and communication tools and 3-D and 4-D modelling in the industry. A possible reason for such a pattern may be the existence of several IT-related academic journals that attract most contributions of this type. Overall the CM and construction economics disciplines, as they have been represented in the journal, have expanded considerably over the years with the addition of new fields of study or sub-disciplines, as shown by the number of topics in Table 5. It is suggested that future CME editorial efforts reflect such a growth and aim at structuring these two disciplines into sub-fields or areas of study according to which future contributions could be organized and published.

CONCLUSIONS

Since its inception in 1983, CME has grown significantly in terms of published papers and contributing authors. This growth has taken place particularly with the single editorship of Will Hughes. In the past four years (2002–06) the number of published issues was more then three times that published in the 1983–86 period, a sign that CM and construction economics have attracted the interest of a wide spectrum of contributors. The progressive growth of CM is also reflected in the launching of several related academic journals around the world. Notwithstanding new competition, CME has been attracting more and more contributions. Over the years the relatively decreasing share of UK authors has been more than compensated for by the explosive growth of authors from Commonwealth countries, particularly in East Asia. This growth is not confined to former UK colonies and territories, but is also reflected in the increasing participation from the rest of the world. The majority of the contributions to CME are from surveying, architecture and engineering academic-related areas. The journal has also attracted a sizeable number of authors from areas not directly related to construction. This wide range of contributing sources suggests that CM and construction economics are recognized as a distinct field of enquiry by members of various disciplines and that, at the same time, CM in particular does not have a single academic locus, as in the case of more established disciplines such as law or medicine. Over the life of CME, contributors have shifted the focus of their scholarly endeavour. The initial emphasis on managing projects has been losing momentum and has been replaced by contributions that are concerned with the operations of firms and matters pertaining to the construction industry at large, both domestically and internationally.

The body of knowledge published in CME has expanded with the addition of new fields of enquiry pertaining to the strategic and operational aspects of firms, and the management of projects (particularly the planning and design phases) and contractual clauses. This growth, however, has not occurred uniformly. The important area of technologies (e.g. construction methods and materials as well as IT applications) has not received enough attention, notwithstanding the fact that technological advances are positively impacting on the performance of highly developed construction industries around the world. In an era of increasing global competition, the impact of technology on improving productivity should not be overlooked.

ACKNOWLEDGEMENTS

The authors wish to thank Dr Will Hughes for providing valuable data for developing this study.

REFERENCES

Bennett, J (1983) Editorial. *Construction Management and Economics*, **1**, 1–2.

Betts, M and Lansley, P (1993) *Construction Management and Economics*: a review of the first 10 years. *Construction Management and Economics*, **11**, 221–45.

Betts, M and Lansley, P (1995) *International Journal of Project Management*: a review of the first 10 years. *International Journal of Project Management*, **13**, 207–17.

Chinowsky, P S and Diekmann, J E (2004) Construction engineering management educators: history and deteriorating community. *Journal of Construction Engineering and Management*, **130**, 751–8.

Pietroforte, R and Aboullezz, M A (2005) *ASCE Journal of Management in Engineering*: review of the years 1985–2002. *Journal of Management in Engineering*, **21**, 125–30.

Pietroforte, R and Stefani, T (2004) *The ASCE Journal of Construction Engineering and Management*: a review of the years 1983–2000. *Journal of Construction Engineering and Management*, **130**, 440–8.

A REVIEW AND CRITIQUE OF CONSTRUCTION MANAGEMENT RESEARCH METHODS

Andrew Dainty[1]

Department of Civil and Building Engineering, Loughborough University, Loughborough, Leicestershire LE11 3TU, UK

As the construction management field has grown and matured over the past 25 years, it would be reasonable to expect that the methodologies employed by researchers will have diversified to reflect the multiple traditions and perspectives from which researchers now draw. An indication of a broadening methodological outlook was reflected in the debate within *Construction Management and Economics* around 10 years ago, in which proponents of both positivist and phenomenological methodologies debated the relative merits of each philosophy and the insights that they provide to social research within the community. This paper examines the extent to which this debate, and the ongoing maturation of the discipline, has resulted in methodological pluralism within the construction management field. A cross-sectional analysis of research published within *Construction Management and Economics* in Volume 24 (2006) reveals that the community's research is still overwhelmingly positivist in its orientation, with a resultant reliance on quantitative methods. Of the small number of studies that employed interpretative methods, the majority relied exclusively on open-ended interviewing. The findings of this analysis have fundamental implications for the efficacy and validity of research which seeks to understand the social worlds of those who work in the industry. It is argued that the apparent lack of methodological diversity and adventure in interpretative research design renders the community unable to provide a rich and nuanced understanding of what it means to 'do' construction management. The findings will, however, be reassuring to those who see interpretivism as unscientific and positivism as an insurance against 'bad science'.

Keywords: interview, methodology, research methods, sociology.

INTRODUCTION

As a research discipline which lies somewhere between the natural and social sciences, for many years construction management has been subject to the ascendancy of positivism and quantitative method (Fellows and Liu 2003). In the mid-1990s *Construction Management and Economics* hosted a philosophical debate on the role of theory in construction management and the research paradigm of construction management researchers. This debate was initiated by two papers in particular (Seymour and Rooke 1995; and Seymour *et al.* 1997), which questioned the dominance of rationalist research paradigms and the value of theory within construction management research. They invoked a vigorous and somewhat polarized debate around the relative merits of different research paradigms. In their papers, Seymour and Rooke (1995) and Seymour *et al.* (1997) implicitly questioned the dominance of the rationalist position which seemingly underpinned most research within the community. They suggested that this tacitly endorsed the very attitudes in

[1] a.r.j.dainty@lboro.ac.uk

need of change in the industry, and suggested that the culture of research must change if researchers were to have an influence on the industry. In responding to Betts and Lansley's (1993) review of the first 10 years of the journal, Seymour *et al.* (1997) further questioned the dominance of the scientific theorizing associated with realist ontological and epistemological positions given that the 'object' of most construction management research is people. This suggested that the construction management discipline underestimated the interpretive process.

In the debate which ensued, Seymour and Rooke and Seymour *et al.* were subjected to an intellectual 'broadside' from established researchers within the construction management community. Seymour *et al.* (1997) were accused of being 'anti-scientific' and of propagating an approach which has yet to yield productive output, theories or progress (Runeson 1997). Further, they were accused of promoting an approach more akin to consultancy than research, and of advocating methods which themselves have been widely criticized within the sociological literature (Harriss 1998). Seymour and Rooke (1995) were accused of setting out battlelines in the way that they dichotomized rationalist and interpretative paradigms to the detriment of research standards (Raftery *et al.* 1997). Seymour and colleagues defended their position by counterclaiming that Raftery *et al.* (1997) themselves undermined standards by failing to recognize that different methods suit different purposes and that their position was symptomatic of the widespread confusion over terms such as 'method', 'methodology' and 'paradigm' (Rooke *et al.* 1997). They also questioned Runeson's definition of 'science', defending the rigour of the methods associated with the interpretive paradigm and their value in establishing the meaning ascribed by the social actors being studied (Seymour *et al.* 1998). Various other authors weighed into the debate (e.g. Edum Fotwe *et al.* 1997), with some questioning its value given the apparent focus on research methods as opposed to methodology (Root *et al.* 1997). At the time, some researchers went to greater efforts to explain the philosophical position underlying their research.[1] And then the debate dissipated.

More than a decade later, a series of questions emerge in terms of the legacy of this debate in terms of the impact it has had on construction management research. For example, have alternative research paradigms been embraced, or did the construction management community merely revert to its traditional adherence to positivism and quantitative methods? Furthermore, has there been a move towards mixing paradigms and methods, or have the rival camps within the construction management community remained entrenched and dichotomized within their own epistemological communities? This paper aims to attempt to provide some answers to these questions, *not* in an attempt to reignite the polarized debates around the relative merits of different methodologies and research paradigms, but to establish whether the debate has had a lasting legacy on the way in which the construction management community now 'does research'. It examines the methods utilized by researchers in the most recent complete volume of *Construction Management and Economics* as an indication of the extent to which methodological pluralism has been embraced. In addition, it examines the types of interpretative research methods applied by construction management researchers and questions. Thus, the results reveal both how the construction management research community has responded to the philosophical questions asked of it in the mid-1990s, and the diversity of research approaches that this has induced. The ensuing discussion speculates as to the likelihood of the insights gained through these research approaches informing the development and evolution of the industry that it serves.

RESEARCH STRATEGY AND DESIGN

As a precursor to investigating the methods adopted by construction management researchers, it is necessary to review briefly the decisions which underlie research methodology, strategy and design. Such an understanding enables the appropriateness of decisions as to the most appropriate method to be understood and evaluated in relation to the production of knowledge. Clearly, research methodology in social enquiry refers to far more than the methods adopted in a particular study and encompasses the rationale and the philosophical assumptions that underlie a particular study. These, in turn, influence the actual research methods that are used to investigate a problem and to collect, analyse and interpret data. In other words, research methods cannot be viewed in isolation from the ontological and epistemological position adopted by the researcher.

Objectivist ontology sees social phenomena and their meanings as existing independently of social actions, whereas constructivist ontology infers that social phenomena are produced through social interaction and are therefore in a constant state of revision (Bryman and Bell 2003: 19–20). Epistemology refers to what should be regarded as acceptable knowledge in a discipline (*ibid*.: 13). Epistemological perspectives are bounded by the positivist view that the methods of the natural sciences should be applied to the study of social phenomena, and the alternative orthodoxy of interpretivism which sees a difference between the objects of natural science and people in that phenomena have different subjective meanings to the actors studied. Understanding the influence that competing paradigms have on the way in which research is carried out is fundamental to understanding the contribution that it makes to knowledge. Taking Kuhn’s (1970) definition of a paradigm as a cluster of beliefs and dictates of how research should be done, different research paradigms result in the generation of different kinds of knowledge about the industry and its organizations. The choice of which paradigm to adopt fundamentally affects the ways in which data are collected and analysed.

In broad terms, the term ‘research design’ refers to the process of situating the researcher in the empirical world and connecting research questions to data (Denzin and Lincoln 1994). In other words, it describes the ways which the data will be collected and analysed in order to answer the research questions posed, and so provides a framework for undertaking the research (Bryman and Bell 2003: 32). Making decisions about research design is fundamental to both the philosophy underpinning the research and the contributions that the research is likely to make. For example, qualitative research stresses ecological validity, the applicability of social research findings to those that exist within the social situation studied. Choosing a reductionist approach to examining social phenomena (such as a questionnaire survey) is likely to distance the enquiry from the social realities of the informant, thereby undermining its ecological validity. Thus, methods are inevitably intertwined with research strategy.

In this paper a distinction is drawn between ‘quantitative’ and ‘qualitative’ research. While this distinction is considered by some as unhelpful (see for example Layder 1993), it nevertheless provides a useful framework for categorizing the methods used by researchers. Indeed, it can be argued that quantitative and qualitative research are rooted in particular ontological and epistemological foundations (i.e. objectivism and constructivism, and positivism and interpretivism respectively). Accepting this association between research methods and research paradigms enables philosophical differences in the role that theory plays in research to be viewed through the lens of the methods employed by researchers. Thus, in this research, the methods employed are used as a proxy for the paradigm adopted. It is accepted that this represents an oversimplification of reality. For example, it is plausible that qualitative methods can be employed for theory testing as well as theory generation. However, as will be discussed later in this paper, this is the case in the vast majority of construction management research projects.

QUALITATIVE RESEARCH METHODS

This paper is primarily concerned with the extent of the use of qualitative research methods, which tend to be those associated with the interpretive research paradigm. Qualitative research involves an in-depth understanding of human behaviour and the reasons that govern human behaviour, and so in contrast to quantitative approaches, seeks to establish reasons behind various aspects of behaviour (Wikipedia 2007). There is not room within this paper for an in-depth treatise on the multiplicity of methods that fall under the broad heading of qualitative research (see Denzin and Lincoln 2000; Cassell and Symon 2004; and Silverman 2004, 2005 for this). Moreover, it is important to stress that qualitative research methods is a complex, changing and contested field (Denzin and Lincoln 2000) which is characterized by its diversity (Punch 2005: 134). This is perhaps unsurprising given the inherently subjective nature of qualitative data analysis, whereby the researcher continually shuttles between data analysis, reduction, display and theory generation. Some writers (e.g. Silverman 2003) are overtly critical of attempts to classify qualitative research methods into generic types. This becomes particularly problematic when the ambiguity between theory and research is considered, which is a hallmark of the inductive research paradigm, and the centrality of the subjective interpretation and situational embeddedness of the researcher within qualitative enquiry. However, despite these problems of classification, it is possible to categorize qualitative research methods in broad terms, while accepting that the application of these methods and the interpretation of the results will differ from researcher to researcher.

Although there is no definitive taxonomy of qualitative research methods, a broad classification can be gleaned by examining the classification of methods adopted by leading texts in this area (e.g. Denzin and Lincoln 2000; Bryman and Bell 2003; Cassell and Symon 2004; and Silverman 2005). A brief description of the primary methods used in qualitative research is provided below based on a synthesis of these sources. This broad classification is used to evaluate the methods adopted by researchers publishing in *Construction Management and Economics* later in this article.

Observation and ethnography

Observation can be in two main forms, participant and non-participant. Participant observation is often associated with ethnography, although ethnography refers to both the written output of the research as well as the research and the method. Both approaches involve entering the context of the research as a participant with data usually taking the form of field notes. It often requires a sustained period of intensive work because the researcher needs to become accepted as a natural part of the culture being studied in order to ensure that the observations are of the natural phenomenon. Non-participant observation differs in that the observer attempts to unobtrusively observe the phenomena under investigation. This more detached perspective tends to be more time bounded. Both forms involve profound ethical considerations.

Discourse and conversation

Discourse and conversation analysis are both concerned with the examination of language. Conversation analysis comprises the in-depth examination of talk as it occurs (usually through transcribed discussion) through which the structures of language can be uncovered. Discourse analysis can be applied to any form of text (i.e. there is not an emphasis on naturally occurring talk). The emphasis is on establishing the way in which the social world is constructed through discourse – what is written, said (or not said) – and how this impacts on others' perceptions and experienced realities.

Document and textual analysis

This refers to the analysis of any kind of textual data from personal documents to internet resources. The common feature is that these are secondary sources of information that have not been produced for the purposes of the research study.

Visual data

A relatively recent addition to what are considered qualitative methods is the analysis of visual data. These can include photographs, video, pictures (e.g. cartoons) and any other visual media which convey information on a social situation or setting.

Interviews

Qualitative interviews can either be unstructured or semi-structured. Interviewing involves direct interaction between the researcher and a respondent or group, but whereas semi-structured interviews may follow a framework of questions, unstructured interviews are left to develop naturally around the topic of discussion. In both cases the interviewer is not constrained by a rigid instrument and is free to move the conversation in different directions as relevant issues emerge. A variation on individual workshops is focus groups where the emphasis is on engaging several informants in the joint construction of meaning.

Case studies

Although often referred to as a method, there is no single way to conduct case study research and it will often comprise a number of mutually supportive methods and research designs, some of which may be quantitative. In this study the individual methods used within the case have been categorized within the analysis.

METHOD

In order to examine the methodological positions and research methods adopted by construction management researchers, an analysis was carried out of every paper published in *Construction Management and Economics* in Volume 24, 2006. Each paper was scrutinized for statements as to the methodological position of the author(s) and the methods employed. Where this was not unambiguously stated within a defined section of the paper, efforts were made to identify the methods adopted from the narrative description of the research. In some cases no discernible empirical research methods were adopted as the paper was a review-type contribution. In other cases papers drew upon a multimethodological or multi-paradigm research design. These papers were defined as 'review' and/or 'mixed methods' respectively. Thus, four broad classifications were used for summarizing the methodologies adopted within the papers as follows:

1. *quantitative* – unambiguously adopting quantitative methods rooted in a positivist research paradigm;
2. *qualitative* – unambiguously adopting qualitative methods rooted in an interpretative research paradigm;
3. *mixed methods* – comprising a combination of both inductive and deductive research methods;
4. *review* – not utilizing empirical research methods.

For those papers which reported research which adopted a qualitative (2) or mixed method (3) approach, a further sub-classification step was undertaken to categorize the methods used. These categories were established inductively and were not based on an *a priori* classification of research methods. In this respect, the interpretation of the methods adopted by the papers' studies is itself interpretative. This was necessary as some authors did not unambiguously state their adopted methods. The qualitative methods adopted by the authors can be summarized thus:

1. interviews (semi-structured and unstructured);
2. focus groups and group interviews;
3. observation (non participatory and/or participatory including ethnography);
4. document or other textual analysis;
5. visual data analysis.

It is important to stress that there are several significant limitations of the approach adopted. First, the papers published within *Construction Management and Economics* may not be reflective of the entire construction management research community. A search of papers published in other journals may have revealed that they attract papers from a different constituency of the research community which adopt different research methods. Secondly, this study represents an analysis of only those papers published and not *submitted* to the journal. As such, the analysis may be more representative of the biases of referees rather than being necessarily representative of the methods actually adopted by construction management researchers. A third limitation concerns the nature of the methodological description contained within the papers themselves. This is highly variable and renders any such analysis somewhat tenuous. In addition, it is possible within some of the projects that other methods were employed which have not been unambiguously stated within the papers. These aspects may not have been published or may have been published elsewhere for legitimate reasons (such as word restrictions placed on articles within the journal). A fourth issue concerns the reliability of drawing general conclusions based on a single year's worth of papers. It is possible that papers published in this year were anomalous to the general trends the kind of papers published within the journal. A final issue is that not all of the papers published within the journal can be described as 'social research'. For example, some papers dealt with aspects of construction law or finance, which have only loose connections to social phenomena, for which the utilization of qualitative methods would have been inappropriate. Despite these weaknesses, however, the journal is considered by many construction management researchers to be one of the leading refereed publications in its field. This is supported by the very high levels of copy flow and the high rejection rate (see Taylor and Francis 2007). Furthermore, it is reasonable to assume that, given that reviewers of papers are drawn from the construction management research community, that any bias towards methodological approaches would balance itself out over time. The year selected for analysis, 2006 was the most recent year for which a full year's worth of papers was available. Furthermore, the journal switched to a 12-issue format in 2006 which enables more papers to be considered in the analysis. Thus, while this paper makes no claims as to the statistical reliability of the findings presented, and draws upon a qualitative analysis of the narrative description of the methods employed within the papers, it does enable a simplified cross-sectional view of the dominant position of the research community.

RESULTS

The results of the analysis are presented in Tables 1 and 2. Table 1 presents an overview of the methods used within the research reported in the papers reviewed. These data represent the number of papers utilizing the methods embodied by the broad classifications listed above. This shows that of 107 papers and notes published in Volume 24 of the journal, 76 used quantitative methods. Only nine used qualitative methods exclusively. In addition, a further 12 papers used a mixed methods approach combining qualitative and quantitative methods. It should be noted that in a few of the studies which have been classified as utilizing exclusively quantitative approaches, a brief mention of exploratory interviews was made, although none of these data was reported in the data. Although it could be argued that the qualitative findings may have shaped the resulting enquiry and quantitatively derived results, the fact that they didn't warrant reporting in the papers provides justification for excluding them from the 'mixed methods' classification.

Table 1: Broad classification of research methods reported in all papers (excluding letters and book reviews) in Vol. 24 of *Construction Management and Economics* (n = 107)

	Qualitative methods	Quantitative methods	Mixed methods	Review/other papers
No. of papers	9	76	12	10
(% in parenthesis)	(8.4)	(71.0)	(11.2)	(9.4)

Table 2 presents a breakdown of the types of qualitative methods employed by those employing only qualitative methods and those adopting a mixed methods approach. In this table, papers have been classified under each category if the particular method has been utilized and the results reported in the paper. Thus, this table reflects the *number of times that a method was applied* across the sample of papers. Given that several studies employed a number of methods and datasets, this number is greater than the number of papers identified in Table 1. This table reveals that 16 of the 105 papers published in Volume 24 of the journal used individual open-ended interviews. This represents more than three-quarters of the studies employing qualitative methods. Three studies used focus groups, workshops and/or group interviews, two used forms of observation and three analysed documentary data (mainly as part of case study research). Only one project reported analysing visual data.

Table 2: Classification of research methods reported in papers using qualitative research methods in Vol. 24 of *Construction Management and Economics*[2]

	Interviews	Focus groups, workshops and group interviews	Observation	Document or textual analysis	Visual data
No. of papers	16	3	2	3	1

DISCUSSION

Clearly, the construction management research community has grown and developed since the methodological debates of the mid-1990s. This is demonstrated by the growth in the number of papers published in the discipline's leading journals. As academic departments and facilities have expanded and the numbers of doctoral candidates undertaking construction management research have increased, it could be reasonably expected that their methodological positions and the methods adopted may have broadened and diversified also. However, if the contents of the volume of *Construction Management and Economics* reviewed here are reflective of the community at large, then this is manifestly not the case. The findings raise fundamental questions, both in relation to the narrow ontological and epistemological standpoints of the research community, and in relation to the uniformity of methods that interpretive researchers employ.

Questions of social ontology are concerned with whether social entities are objective realities or social constructions built up from the actions and perspectives of social actors (Bryman and Bell 2003: 19). It would seem on the basis of this analysis that the majority of construction management researchers have retained an objectified view of reality. While it is by no means certain that the predominance of quantitative methods revealed in this paper is inexorably linked to positivist research philosophies,[3] it is highly likely that this reflects an ongoing adherence to natural science methodologies and reductionist approaches to social enquiry within the community. Whether this should be seen as a concern will depend upon the individual standpoint of the reader, but the construction management community's apparent reluctance to embrace methodological pluralism has undoubted implications for the contribution it makes to both research scholarship *and* practice given that much construction management research is based on the co-production of knowledge between researchers and practitioners. It would seem that the research community has continued to adopt a rationalist paradigm in seeking to theorize on construction management as a discipline, with a resultant emphasis on causality over meaning (cf. Seymour and Rooke 1995; Seymour *et al.* 1997). It could be argued that the research community reflects, in microcosm, the industry's wider adherence to instrumentalist and rational solutions to complex managerial problems and situations (see Dainty *et al.* 2007).

A second issue emerging from this analysis concerns the apparent reliance of qualitative construction management researchers on open-ended interviewing. As was discussed above, in contrast with quantitative research design, which remains relatively methodologically unidimensional, contemporary qualitative research is characterized by its diversity (Punch 2005: 134). However, in the volume of *Construction Management and Economics* reviewed, virtually all of the studies which employed exclusively qualitative methods relied exclusively on semi-structured interviews. Within the social sciences, the apparent over-reliance on interviewing has been attracting criticism from researchers who see it as symptomatic of the 'interview society',[4] and of belying the fact that interviews are themselves methodologically constructed social products and not 'experientially authentic truth' (Gubrium and Holstein 2002). In the past, those critical of interviewing have questioned their efficacy based on practical and pragmatic considerations such as the truthfulness of the informant and the differences between what people say and what they actually do (see Hammersley and Gomm 2005). However, a more radical critique of interviews as a research method has recently emerged in which the social construction of what is said, and the fact that they reflect the particular context within which they take place, has been seen as limiting their methodological validity. Such a critique sees the interview informant as being more focused on self-presentation and the persuasion of others, rather than on presenting facts about themselves or the world in which they exist (*ibid*.). Regardless of whether such a radical perspective on the efficacy of interviews is fully accepted, the acknowledgement that they are in any way flawed reinforces the need for data from different sources to triangulate the implications and outcomes that they provide.

An emergent finding warranting further discussion concerns the lack of reflexivity within the papers reviewed. As was alluded to above, there is a tradition of reflexivity in qualitative enquiry where researchers openly question the effectiveness of their research methods on the robustness of their results and debate the influence and effect that their enquiry has had on the phenomena that they have sought to observe. Being reflexive requires a willingness to probe well beyond straightforward interpretation of the data to explore how personal research bias affects the research process itself (Woolgar 1988). Despite this, however, there is an absence of any critical reflection in many of the papers reviewed which adopted qualitative methods. This may reflect that dominant rationalist paradigm of the construction management research community, or even a concern on the part of interpretative researchers that such a reflection would effectively equate to admission of 'fault' in their research designs. However, an apparent reluctance to engage in reflexivity arguably has a detrimental effect on the methodological evolution of the discipline and the development of its theoretical base.

CONCLUSIONS

More than a decade on since the methodological debate invoked by Seymour and colleagues, this paper has revealed that the construction management field appears to have remained firmly rooted within the positivist tradition. It has shown both an entrenched adherence to positivist methods within the community, and a significant reliance on open-ended interviews by those adopting qualitative methods. Clearly, no claims can be made as to the broader significance of these findings as they do not provide evidence of methodological trends, but they do provide limited evidence of an apparent reluctance to embrace paradigmatic change within the construction management community. Moreover, they present a view of a community reluctant to adopt the kinds of radical qualitative research methods which could provide richer insights into industry practice. Contemporary critiques on interviewing methods suggest that they are exceptionally poor at revealing anything beyond the immediate interview situation. Indeed, if interviews are considered to be methodologically constructed social products, then this has worrying implications for the efficacy and validity of qualitative construction management research which has sought to understand the social worlds of those who work in the industry.

For some, the conclusions of this paper will be deeply worrying on several levels. The apparent lack of methodological diversity coupled with an apparent lack of adventure in interpretative research design suggests a research community rooted in methodological conservatism and disconnected from the debates going on in many of the fields from which it draws. They will see construction management researchers as needing to adopt a more pluralistic attitude towards the selection of research methods if they are to develop a richer and more nuanced understanding of the sociology of the industry and its organizations. On the other hand, those who see interpretivism as unscientific and positivism as an insurance against 'bad science' will be reassured that the field has not embraced calls for paradigmatic change.

NOTES

1. The present author was writing up his PhD thesis at the time of this debate, and dedicated over 50 pages of his thesis to justifying the ontological and epistemological position adopted in his work!
2. It should be noted that on several occasions the nature of the data collected and the methods employed were ambiguous. Although a reasoned judgement has been made based on the contents of the paper and the nature of the results, the accuracy of these assertions cannot be guaranteed given the lack of detail within the papers.
3. Surprisingly few of the papers reporting on social research actually stated a methodological position within the volume reviewed. The majority of those that do discuss their research design tended to discuss only the methods employed and not the philosophical assumptions that underpinned their research.
4. An obsession on the part of the mass media to uncover the personal realities which underlie the public facades of the interview subject.

REFERENCES

Betts, M and Lansley, P (1993) *Construction Management and Economics*: a review of the first ten years. *Construction Management and Economics*, **11**(4), 221–45.

Bryman, A and Bell, E (2003) *Business research methods*. Oxford: Oxford University Press.

Cassell, C and Symon, G (2004) *Essential guide to qualitative methods in organizational research*. London: Sage.

Dainty, A R J, Green, S D and Bagilhole, B M (2007) People and culture in construction: contexts and challenges. *In*: A Dainty, S Green and B Bagilhole (Eds.) *People and culture in construction: a reader.* Oxford: Taylor and Francis.

Denzin, N K and Lincoln, Y S (Eds.) (2000) *Handbook of qualitative research*. 2ed. Thousand Oaks, CA: Sage.

Fellows, R and Liu, A (2003) *Research methods for construction.* 2ed. Oxford: Blackwell.

Gubrium, J F and Holstein, J A (2002) *Handbook of interview research*. Thousand Oaks, CA: Sage.

Hammersley, M and Gomm, R (2005) Recent radical criticism of the interview in qualitative inquiry. *In*: *Developments in sociology*, Vol. 20. Ormskirk: Causeway Press.

Harriss, C (1998) Why research without theory is not research. A reply to Seymour, Crook and Rooke. *Construction Management and Economics*, **16**, 113–16.

Kuhn, T S (1970) *The structure of scientific revolutions*. 2ed. Chicago: University of Chicago Press.

Layder, D (1993) *New strategies in social research*. Cambridge: Polity.

Punch, K (2005) *Introduction to social research*. 2ed. London: Sage.

Raftery, J, McGeorge, D and Walters, M (1997) Breaking up methodological monopolies: a multi paradigm approach to construction management research. *Construction Management and Economics*, **15**(3), 291–7.

Rooke, J, Seymour, D and Crook, D (1997) Preserving methodological consistency: a reply to Raftery, McGeorge and Walters. *Construction Management and Economics*, **15**, 491–4.

Root, D, Fellows, R and Hancock, M (1997) Quantitative versus qualitative or positivism and interactionism – a reflection of ideology in the current methodological debate. *Journal of Construction Procurement*, **3**(2).

Runeson, G (1997) The role of theory in construction management research: comment. *Construction Management and Economics*, **15**(1), 299–302.

Seymour, D and Rooke, J (1995) The culture of the industry and the culture of research. *Construction Management and Economics*, **13**(6), 511–23.

Seymour, D, Rooke, J and Crook, J (1997) The role of theory in construction management: a call for debate. *Construction Management and Economics*, **15**(1), 117–19.

Seymour, D, Crook, J and Rooke, J (1998) The role of theory in construction management: reply to Runeson. *Construction Management and Economics*, **16**, 109–12.

Silverman, D (1993) *Interpreting qualitative data: methods for analysing qualitative data*. London: Sage.

Silverman, D (Ed.) (2004) *Qualitative research: theory, method and practice*. 2ed. London: Sage.

Silverman, D (2005) *Doing qualitative research: a practical handbook.* 2ed. London: Sage.

Taylor and Francis (2007) *Statistical summary of annual performance for construction management and economics*. Available at www.tandf.co.uk/Journals/pdf/announcements/rcme_stats.pdf (accessed February 2007).

Wikipedia (2007) *Qualitative research*. Available at http://en.wikipedia.org/wiki/Qualitative_methods (accessed February 2007).

Woolgar, S (1988) *Science: the very idea*. Chichester: Ellis.

TRIGGERS FOR HOUSING DEVELOPMENT

Philippe Thalmann[1]

Ecole Polytechnique Fédérale de Lausanne, EPFL ENAC INTER REME, Station 16, CH-1015 Lausanne, Switzerland

What leads to the development of residential construction projects? If the economic literature is to be believed, developers analyse market opportunities. However, it is difficult to assess those opportunities, for several reasons, e.g. long time horizon for developers who intend to remain owners of the completed dwellings and no coordination between developers. The latter problem concerns particularly developers who intend to sell their project upon completion (market developers). Is housing development really predominantly the result of market analysis? Micro analyses reveal that particular circumstances also play an important role: the availability of a particular piece of land, financing conditions, land regulation, etc. This article is designed to assess the shares of projects that are initiated on the basis of market analysis as opposed to other trigger factors. If that share is small, it is unlikely that house building can be explained or predicted with standard economic models of supply and demand. It also means that macroeconomic housing policy (lowering interest rates, subsidies designed to increase profitability, even rent deregulation) will not be very effective. A unique database was created by surveying 2257 developers who built multi-unit residential buildings in the 1990s in Switzerland.

Keywords: housing development, housing policy, property development, Switzerland.

INTRODUCTION

The importance of understanding the drivers of housing supply is amply documented, e.g. for the UK by Ball (1996a and 1996b). What leads to the development of residential construction projects? If mainstream economic literature is to be believed, developers analyse market opportunities and maximize their profit intertemporally. When they see sufficient demand for new developments and expect to earn an adequate return on their investment, they purchase land and the other resources needed to make dwellings, produce them and put them on the market. In other words, supply responds to demand. Only the unavoidable delays between the observation of adequate market conditions and delivery of new dwellings can cause disequilibria on the housing market, which vanish as soon as developers have a chance to adjust their supply (e.g. Kenny 2003). For surveys of the housing supply literature, see DiPasquale (1999).

The surge of behavioural economics is renewing the interest in economic decision making. Scanlon and Whitehead (2006: 25) recently did so for private landlords in the UK and concluded that 'individual private landlords do generally respond to economic stimuli in rational ways'. However, they found ample evidence of short-sightedness, asymmetry in responses to changing opportunity costs, insufficient consideration of opportunity costs, and liquidity constraints. De Bruin and Flint-Hartle (2003) tested whether a bounded-rationality model better describes the investment choices of

[1] philippe.thalmann@epfl.ch

individual landlords in New Zealand. They found that most had bought property for the capital gains promised, but they had done so at a time when inflation was clearly under control, which suggests backward-looking behaviour. They also find evidence of bounded rationality in the fact that investors' portfolios are very little diversified.

Indeed, the simple profit-maximizing model of housing supply can be challenged on several grounds. It is difficult for developers to be aware of what their competitors are preparing, so they might answer to the same perceived demand with excess supply. On the other hand, not all developers need to make their profit from the immediate sale of their product. Many have the option and choose to remain owners of the new buildings and rent them, so that the return on the investment can be earned gradually over time. This complicates considerably the developer's calculation of profit opportunities. It also makes it very difficult for outside observers to test whether developers are really performing a thorough project analysis before launching a development. Expectations ought to play a much more important role than current market conditions, and expectations are notoriously hard to observe. Scanlon and Whitehead (2006) observed that fact when testing the rationality of private landlords in the UK. They noted that the same market signal may just as well justify an increase in housing investment as a decrease. Consider an increase in property prices. It implies smaller rental return and greater risk. It can even be taken as a signal of future price corrections (mean reversion). On the other hand, property price increases signal rising housing demand. It takes a thorough analysis of price changes to predict their consequences for future profitability and even experts disagree on them.

Experts even disagree on how the profitability of housing investment ought to be assessed. Some ignore its capital gains component (Skifter Andersen 1998). Some consider that landlords are irrational if they do not leverage their property to take advantage of low mortgage interest rates (Ball 2004) while others might consider that the risks and unattractive investment alternatives for the freed equity justify full ownership for many landlords. Even decreasing stock market prices need not command a portfolio reallocation in favour of rental property, as many financial advisers recommend targeting fixed portfolio shares, which implies buying more shares when stock markets slump.

In the face of difficult project analysis, many developers might use shortcuts and place their faith in the long life expectancy of their products, which can generate adequate returns when given sufficient time. They might launch developments when local circumstances are favourable (e.g. a neighbour develops her property) or some other fortuitous event occurs (e.g. the developer is proposed a plot of land). On the other hand, partial negative signals such as rising land or construction prices, a slack in economic growth or a spike in vacancies may discourage them from developments that thorough analysis might still show to be profitable.

This article is designed to assess the shares of projects that are initiated on the basis of market analysis as opposed to other trigger factors. If that share is small, it is unlikely that house building can be explained or predicted with standard economic models of supply and demand. It also means that macroeconomic housing policy (lowering interest rates, subsidies designed to increase profitability, even rent deregulation) will not be very effective.

It seems that the only way to learn about the triggers of housing developments, in particular the importance of market conditions and housing needs, is to ask developers. This is what this paper does. It draws from a survey that is part of a wider research project designed for understanding why housing construction had declined so much in the second half of the 1990s in Switzerland in spite of apparently quite favourable conditions. The results of that project were published as Schüssler and Thalmann (2005).

CONTEXT OF THIS RESEARCH

In Switzerland, rental housing accounts for about one-half of all new developments and it still houses about two-thirds of all households.[1] Moreover, it houses the households that have least housing choices and tend to suffer most from housing shortage. The Swiss case study is also interesting for the country's long history of housing shortage. Observers consider that the market is balanced when the national vacancy rate reaches a mere 1.5%, a rate that was only exceeded in four of the last 30 years. The question of why there is not more housing development and what triggers development is clearly warranted on such a market.

The Swiss market is also characterized by its high fragmentation: 57% of all rental dwellings belong to private individuals (2000 Census).[2] The rest belongs to a myriad of small pension funds, small cooperatives, local authorities and very few large institutional investors. There are over 4000 construction firms in main construction (not counting painters, etc.), so that the average construction volume per firm is less than a million euros and the average number of personnel is around 20. Finally, over 40% of all dwellings are developed by individuals and a third by the myriad construction firms and real estate companies. Thus, developers are just as fragmented as the rest of the market.

We shall see that it is necessary to distinguish between market developers, who build with a view to selling the completed building to final investors (who include users in condominium ownership), and final investors who build themselves. The difference is that market developers need to anticipate investors' desire to invest. There is an intermediate solution, whereby the market developer develops a project at the request of an investor. This last solution is rather uncommon in Switzerland.

Developers are not registered as such. They are construction firms, real estate companies, architects, and many individuals (Table 1). To find them, we used the systematic record of construction permits compiled by the periodical *Baublatt/Batimag*. The purpose of that publication is to allow small contractors to learn about building projects and offer their services. We restricted our analysis to buildings containing two dwellings or more in order to eliminate all the single-family developers, who are generally the occupants themselves in Switzerland. In addition, we focused on building permits delivered in two specific periods: 1994–96 and 1999–2001. The first was a period of relatively high housing construction and the second was a trough.

Table 1: Shares of different types of developers in population and sample

	All new dwellings	New dwellings in multi-family units	2004 survey
Public sector	1.9	2.7	1.2
Institutional investors	4.7	6.7	6.1
Construction firms and real estate companies	33.8	37.3	27.1
Cooperatives	3.3	4.4	7.3
Private persons	41.7	32.0	39.1
Other developers	14.5	16.8	19.1

Notes: Data from Federal statistical office in first two columns; averages over 1994–96 and 1999–2001. The total of each column is 100%.

We administered in the summer of 2004 a survey to one-sixth of all 8695 developers who had obtained exactly one building permit for a building with at least two dwellings between 1994 and 1996 or between 1999 and 2001 ('one-shot developers') and to all 808 developers who had realized more than one project in that period ('repeat developers'). That makes 2257 addressees in a population of 9503. The survey had about 60 questions designed to identify the main determinants and triggers of house building and the hurdles and barriers developers face. The results presented here are based on the returns from 316 one-shot builders and 200 repeat builders. They represent 23% of the initial sample or 5.4% of the population. Based on the number of dwellings the respondents declared they had built in the two periods, they also represent about 22% of all dwellings built in multi-family units.

The relatively low rate of return on our survey can be explained by several factors. Many developers no longer existed as an organization or at the old address in 2004, particularly those who had built in the mid-1990s. In addition, addressees who had obtained a building permit for a transformation or renovation were asked not to respond, and that concerns about one-third of all building permits. Nevertheless, our final sample is quite representative of the population of developers (Table 1). Only private persons are somewhat over-represented and construction firms and real estate companies under-represented in our survey.

THE MAIN CATEGORIES OF DEVELOPERS

For understanding development triggers, it is essential to distinguish between short- and long-term oriented developers:

1. Developers who seek to sell the completed dwellings or building with a profit; we shall call them 'market developers'.
2. Developers who build with a view to keeping ownership of the completed building; we shall call them 'investor developers'.
3. Developers who sometimes sell the completed dwellings or building and sometimes keep the completed building; we shall call them 'market/investor developers'.

Table 2 indicates the proportions of each category of developer in the two periods of analysis. The strong increase in strata ownership development accounts for the progression of the share of market developers: in 1999–2001, almost 60% of the projects were built by market developers who sold the flats to individual buyers. Those developers are classified as 'market developers' or 'market/investor developers' depending on whether they also built dwellings that they did not sell.

Table 2: Importance of the categories of developers in 1994–96 and 1999–2001, based on 2004 survey

	Mid-1990s	**End 1990s**
Market developers	22	43
Market/investor developers	30	33
Investor developers	48	24

Notes: Answers of 449 developers. The total of each column is 100%.

Finer distinctions can be made within each category to understand their mode of operation and the triggers that lead them to initiate a housing development. We shall consider in turn market developers and investor developers. The answers of the market/investor developers will be used in both sub-samples.

THE TRIGGERS OF DEVELOPMENT BY MARKET DEVELOPERS

A central distinguishing characteristic among market developers is the frequency with which they launch developments. Those who build repeatedly are assuredly more ‘professional’ than those who build only once in their lifetime.[3] Table 3 shows that there are almost as many market developers who build regularly as market developers who build rarely. In what follows, we shall call the former ‘frequent market developers’ and the latter ‘occasional market developers’.

Table 3: Shares of market developers by frequency of developments, 2004 survey

They develop multi-family buildings …	
… frequently, always for the same investor or group of investors	15
… frequently, for different investors	38
… rarely	35
… never except that unique time	12

Notes: Answers of 323 market or market/investor developers. The total of the column is 100%.

The types of organizations that act as market developers are described in Table 4. It is interesting to note the high proportion of individuals, particularly among the occasional market developers. Nevertheless, construction firms and architects dominate the market, particularly among the frequent market developers. This suggests that market developers often launch a development for the work it provides them, an assumption that was confirmed when we asked them for the main triggers that made them launch a housing development project (Table 5). The somewhat fortuitous opportunity created when someone proposes a plot of land or a construction project comes a close second. Only about one-quarter of the market developers indicated that they launched developments on the basis of their analysis of the market. This is not to say that the other market developers do not analyse the market prior to their developments. It means that very few market developers are actively monitoring the market for business opportunities and therefore likely to respond to housing demand.

Table 4: Types of organizations that act as market developers, 2004 survey

	Occasional market developers	**Frequent market developers**
Individuals	30.4	14.0
Unshared inheritances	6.3	–
General contractors	14.3	36.7
Other construction firms	10.7	7.3
Architects	20.5	25.3
Real estate firms	7.1	10.7
Cooperatives	4.5	3.3
Others	6.2	2.7

Notes: Answers of 262 market or market/investor developers. The total of each column is 100%.

Table 5: Triggers and conditions for launching a housing development project, 2004 survey

Motives that usually lead market developers to launch a housing development project	**Occasional market developers**	**Frequent market developers**
The need to occupy their business capacities	44	70
A piece of land or construction project is proposed	46	62
Their own market analysis	14	30
The demand of a final investor	5	23
Other reasons	25	9

Notes: Answers of 275 market or market/investor developers. Several answers allowed. Column percentages.

We asked market developers how they estimated the profitability of a development project. Their answers are represented in Table 6. Three-quarters indicated that they systematically analyse the project and the local market. That leaves one-quarter who do not, particularly among occasional market developers. Half of the market developers also indicated that they refer to the recent evolution of property prices, which hints at static expectations. Very few refer to the evolution of interest rates and rents, which are important determinants of property prices in theory. Even fewer refer to outside experts.

Table 6: Market developers' references for estimating the profitability of a project, based on 2004 survey

	Occasional market developers	**Frequent market developers**
A systematic project and local market analysis	65	81
The recent evolution of property prices	44	51
The recent evolutions of interest rates	16	19
Consulting experts	16	6
The recent evolution of rents	5	18
Other references	8	10

Notes: Answers of 272 market or market/investor developers. Several answers allowed. Column percentages.

This analysis has shown that market development is dominated by construction and construction-related firms. As a consequence, the main motive for launching developments is the need to keep business resources occupied. Very few projects are launched by market developers on the basis of a market analysis. This does not mean that market conditions play no role. Indeed, even developers who seek the revenue more than the profit perform a systematic project and market analysis and generally require that a minimum share of the project be pre-sold and the financing almost fully assured before they launch a development project. Still, the pressure to generate work, particularly when investors may not hand out too much of it at a time of low construction, might induce construction firms to shortcut some of the market analysis. At the end of the 1990s, there was clearly too little construction by investors in the face of housing demand in Switzerland, as evidenced by a very low vacancy rate. Market developers increasingly became the main suppliers of new housing, in the form of strata ownership. They thus helped strata ownership's share in the housing tenure boom from a very low level (from 4.4% in 1990 to 7.9% in 2000).

Our survey also showed that many market developers are individuals who may develop just one project in their lifetime, typically in response to a fortuitous opportunity, such as the inheritance of a piece of land. It is difficult to assess the importance of that form of housing supply, but since occasional market developers represent almost half of all market developers and since the opportunity of a piece of land or construction project proposed was cited as a trigger by about half of all market developers, it is not implausible that about half of all market developments have that fortuitous character. That creates a large stochastic component in housing supply.

In a nutshell, about half of the market development projects appear fortuitous and only half are based on market analysis. In addition, that market analysis is often tainted by the market developers' wish or need to occupy production capacities. Nevertheless, market developers slowed down the decline in housing construction in the second half of the 1990s, when investors appeared to quit that activity. Let us now turn to the developers who build a property to hold it themselves and try to understand what drives their development decisions.

THE TRIGGERS OF DEVELOPMENT BY INVESTOR DEVELOPERS

All investor developers develop projects to let the apartments, but they can do so with quite different objectives:

1. Developers who seek a profitable investment; we shall call them 'profit driven'.
2. Developers who pursue social goals with their rental dwellings and seek to address housing needs; we shall call them 'social'.
3. Developers who are foremost interested in the work provided by development to occupy their idle capacities; we shall refer to them as 'revenue driven'.

It is quite likely that many in the latter category would have preferred to sell the building like market developers but could not find a buyer on acceptable conditions. The survey shows that all of them are also market developers (they are all 'market/investor developers' in our terminology, see Table 7). Very few social developers act occasionally as market developers. On the other hand, three-quarters of all pure investor developers are profit driven as well as one-quarter of all market/investor developers. Counting over all investor developers, profit-driven developers are the largest category, about half, followed by a third who are mainly revenue driven and 16% social developers. The small share of the latter is no surprise considering that only some 14% of all rental dwellings belong to non-profit landlords (Kemeny *et al*. 2005).

Table 7: Categories of investor developers, based on 2004 survey

	Pure investor developers	Market/investor developers
Profit driven	73	29
Social	27	6
Revenue driven	0	65

Notes: Answers of 149 pure investor developers and 141 market/investor developers. The total of each column is 100%.

The motives of the types of organizations that develop housing to keep it themselves are closely related to their main motivation (Table 8). Thus, insurance companies and pension funds are always profit driven. Foundations and associations, public bodies and cooperatives almost always declared themselves social. Construction firms and architects nearly always build for the revenue. They constitute the lion's share of revenue-driven developers, just as they do among the market developers. It is interesting to note again the importance of individuals, who are the largest category of profit-driven developers and who are also well represented among the other categories of investor developers. Indeed, 57.4% of all rental dwellings in Switzerland belong to individuals (2000 Census).

Table 8: Types of organizations that act as investor developers, 2004 survey

	Profit driven	Social	Revenue driven
Individuals	55.7	20.8	35.1
Real estate firms	6.7	–	7.4
Cooperatives	2.7	50.0	1.1
Insurance companies	4.7	–	–
Pension funds	12.1	–	–
Foundations	–	4.2	–
Public bodies	–	12.5	–
Construction firms	8.1	2.1	26.6
Architects	8.7	2.1	26.6
Others	1.3	8.3	3.2

Notes: Answers of 149 profit-driven, 48 social and 94 revenue-driven developers. The total of each column is 100%.

What triggers housing developments by investor developers? To answer this question, we shall distinguish the categories of investor developers, even though there are many commonalities (Table 9). An important trigger for all is the arrival of interesting projects: more than a quarter of all investor developers cited this as a trigger. Almost as important is the occurrence of favourable circumstances for developing a piece of land the developer already owned. Thus, we find the same fortuitous character in many housing developments as among the market developers. It is naturally particularly important for investor developers who develop projects only occasionally.

Nevertheless, about one-half of the profit-driven developers actively seek investment projects in multi-family rental housing, comparing them with other investment options or not. Almost 30% of the social developers also seek new projects actively. Almost as many of them indicated that it was their job to build, which can be interpreted as dedication to address recurrent housing needs.

Table 9: Triggers of housing developments by investor developers, 2004 survey

	Profit driven	Social	Revenue driven
Build on a piece of land they own when circumstances are favourable	31	29	19
Invest in multifamily buildings when interesting projects present themselves	29	27	27
Continuously seek multifamily projects but also consider other investments	21	0	4
Invest most of their capital in multifamily buildings and actively seek projects	20	29	11
It is their job to build multifamily buildings	12	20	67
Other triggers	1	7	0

Notes: Answers of 138 profit-driven, 41 social and 73 revenue-driven developers. Several answers were allowed but very few gave more than one. Column percentages.

The survey allows for looking more closely at the motivations of each category of investor developers. Profit-driven developers need to assess the profitability of a project, which is made more difficult by the typically very long holding period. Two-thirds of the profit-driven developers in the survey indicated that they assess a project themselves (Table 10). One-quarter rely on their experience and about as many get outside advice. Almost 90% assess a project themselves when we consider only profit-driven developers who built more than 100 dwellings over the past 10 years. Indeed, it is particularly the occasional profit-driven developers who call upon the advice of third parties, typically their banker, or are content with basic evaluation.

Table 10: How profit-driven developers assess a development project, based on 2004 survey

Overall assessment mode	All profit-driven developers	Large profit-driven developers
Performs a financial analysis	66	89
Relies on his/her experience	27	11
Gets outside advice	23	4
Proceeds otherwise	6	4
Specific objective		
The safety of a long-term asset	55	43
The profitability of the investment	33	54
A steady flow of rental income	12	4

Notes: Answers of 144 profit-driven developers, of whom 28 had built 100 or more dwellings over the last 10 years. Several answers allowed. Column percentages.

When they assess a housing development project, most profit-driven developers seek the safety of a long-term real asset (Table 10). This corresponds to De Bruin and Flint-Hartle's (2003: 275) finding that 'wealth accumulation and long-term capital gain was the most important consideration in the property investment decision' for the New Zealand real-estate investors they surveyed 1999. It is only among the large profit-driven developers in our sample that a majority seek the investment's performance. A steady flow of rental income is particularly interesting for pension funds and pensioners. Landlords may also need it to cover the interest and amortization of their mortgage, which is often very high in Switzerland in international comparison.[4]

In summary, a picture emerges that is quite similar to that of the market developers. Two-thirds of the profit-driven developers are sophisticated in the sense that they analyse more or less thoroughly the potentials of a development project while one-third are happy with plain calculations or experience values, or, in the case of market developers, with the preliminary sale on blueprints of at least half of the dwellings.

De Bruin and Flint-Hartle (2003) saw evidence of investors' bounded rationality in the fact that their portfolios were very little diversified. Indeed, 77% of the landlords they had surveyed indicated that residential rental property was the most important investment in their portfolio; 22% held only property. In our survey, only profit-driven developers who were in the database with several building permits, i.e. relatively large developers, were asked about the composition of their portfolio. For half of them, rental housing property accounted for 60% and more of their portfolios. This is clearly much more than portfolio diversification would warrant. Hoesli (1993) shows that the optimal risk–return performance is obtained in Switzerland with a portfolio that includes between 20% and 30% of real estate. There is not even a statistical argument for increasing that share for inflation-hedging purposes (Hamelink and Hoesli 1996).

A project's financial performance is, naturally, less important for social or revenue-driven developers. Still, two-thirds of the latter require a minimum return, typically 5% or 6%, while the other third demand at least that their costs be covered (Table 11). Social developers are split between cost coverage and applying the authorities' regulation (e.g. for subsidized housing), which generally allows for a small return on equity.

Table 11: Profitability requirements for social or revenue-driven developers, based on 2004 survey

	Social	Revenue driven
Does not need profitability, just cost coverage	44	36
Applies the criteria of the authorities	44	2
The return must not lie below some rate	18	63
No consideration whatsoever of profitability	4	0
Other profitability targets	4	6

Notes: Answers of 45 social and 84 revenue-driven developers. Several answers allowed. Column percentages.

In summary, about half of the investor developers are profit driven, mainly individuals and pension funds, one-third are revenue driven, mainly construction-related firms but also individuals, and one-sixth are social, mainly cooperatives and other non-profit developers. Half of the investor developers initiate a housing development when an interesting project is proposed or the circumstances are favourable for a piece of land they own; the other half seek projects for the investment opportunity, for the revenue or to address housing needs. Profit-driven developers generally perform a more or less sophisticated financial analysis of a project but less than half seek profitability first. The safety of a long-lived real asset is more important for small profit-driven developers. Thus, of 100 profit-driven developers, only 13 grade a project relative to their portfolio; 74 require a minimum rate of return but for only 20 is profitability compared to other investments their prime interest. Two-thirds of revenue-driven developers also require some minimum rate of return, whereas social developers are generally happy with cost coverage.

CONCLUSIONS

We probed developers' sophistication in computing the performance of residential investments: Are they forward-looking? Do they weigh risks against returns? Do they assess risks within their portfolios? We probed social developers about the attention they pay to profitability. We also surveyed developers about the intensity with which they seek new projects and the frequency with which they develop projects.

The picture that emerges is that of a heterogeneous population of housing developers. This resembles Beer's (1999: 260) finding from his study of private sector landlords in Australia, that 'individuals invest in rental housing for disparate reasons […] there is therefore a degree of unpredictability within the private rental market, not all investors are likely to respond quickly to changes in investment regimes or market conditions and this is particularly true for those on lower incomes'.

In our survey, the population of housing developers ranges from individuals who develop a project once in their lifetime to exploit the potential of a piece of land they may have inherited to quite sophisticated investors who are continually looking for opportunities to complete their portfolio. The occasional developers are about as important on the market as the repeat developers and private persons supply almost as many dwellings in multi-family units as construction firms and real estate companies together. In that configuration, it is not surprising that every second housing development was initiated for fortuitous reasons. Of course, it is never quite fortuitous that a project is proposed to a developer or that the circumstances become favourable for a piece of land, but the model of the professional developer who continually scans the market and attempts to catch every business opportunity describes only a small part of the market.

At the end of their survey of UK landlords, Scanlon and Whitehead (2006: 23) found: 'Given landlords' general insensitivity to developments in other markets, and the transactions costs problems, it is perhaps more useful to think of landlords as small businesspeople rather than straightforward investors.' This is even more true of housing developers as so many of them indicated as their main motive for housing developments the need to occupy their idle resources. This was less important in the mid-1990s, when housing construction peaked, than in the late 1990s, when it was in a trough. Overall, about half of the dwellings built for sale were built by construction-related firms that primarily sought the revenue. So were many rental dwellings that remained in the ownership of their developers. In earlier periods and other sectors (typically the office market), that development motive has led to overproduction and a protracted excess of vacant spaces. The Swiss housing market of the late 1990s would have dried up even more if it were not for the resilience of the construction firms.

Non-profit developers, who are commonly expected to buffer the withdrawal of traditional developers despite housing shortage, account for only one-sixth of the market. The near full elimination of public housing aid at the turn of the century (Kemeny *et al.* 2005) certainly did not help that category of developers.

With much fewer than half of the housing development projects initiated on the basis of an analysis of housing demand and predicted profitability, it seems preposterous to expect that housing supply reacts to market signals and incentives. It still does because the cues many developers use in place of a thorough feasibility study are not insensitive to market conditions. Thus, when half of the market developers require the sale of a minimum share of the dwellings before they launch a project, that condition is of course more easily satisfied when housing demand is strong. Equally, when half of the investor developers primarily seek the safety of a long-lived asset, they are certainly not blind to the vacancy rate, which is a strong signal of that safety. On the other hand, they may be quite sensitive to reforms that threaten that safety, such as a revision of rent regulation or land planning.

With such a heterogeneous population of housing developers, it is difficult to craft a policy that could help Switzerland retrieve more 'natural' housing vacancy rates than the current 1%. Avoiding unnecessary uncertainty, e.g. over rent regulation, is clearly a part of it. Acknowledging the large contribution of individuals is another one.

ACKNOWLEDGEMENTS

This research was supported by the Swiss Federal Housing Office. I am grateful for comments by Michael Ball and two anonymous referees.

NOTES

[1] More about the Swiss housing market and housing policy can be learned from Kemeny (1995), Lawrence (1996), Werczberger (1997), Thalmann (1997), Hauri *et al.* (2006) and the annual RICS European Housing Review.

[2] This little known fact is not that unusual: a majority of rental dwellings also belong to private individuals in the UK, Denmark, USA and Australia (Scanlon and Whitehead 2006).

[3] Scanlon and Whitehead (2006) made a similar distinction between 'professional' and 'non-professional' landlords. The former own at least three properties; their letting income is at least half of their total income; and they declare financial, business or pension motives for being a landlord. Thus defined, professionals make up 15% of their sample of buy-to-let customers with outstanding mortgage debt in the UK.

[4] Mortgage debt owed by private households residing in Switzerland is 75% of GDP in 1999. Typical financing of housing property is 80% mortgage debt and 20% equity. The mortgage debt is amortized to 60% or 65% of the property's purchase price over 10 to 20 years and generally no further.

REFERENCES

Ball, M (1996a) *Housing and construction: a troubled relationship?* Bristol: The Policy Press.

Ball, M (1996b) *Investing in new housing: lessons for the future*. Bristol: The Policy Press.

Ball, M (2004) *The future of private renting in the UK*. London: Social Market Foundation.

Beer, A (1999) Housing investment and the private rental sector in Australia. *Urban Studies*, **36**(2), 255–69.

De Bruin, A and Flint-Hartle, S (2003) A bounded rationality framework for property investment behaviour. *Journal of Property Investment and Finance*, **21**(3), 271–84.

DiPasquale, D (1999) Why don't we know more about housing supply? *Journal of Real Estate Finance and Economics*, **18**(1), 9–23.

Hamelink, F and Hoesli, M (1996) Swiss real estate as a hedge against inflation: new evidence using hedonic and autoregressive models. *Journal of Property Finance*, **7**(1), 33–49.

Hauri, E, Steiner, V and Vinzens, M (2006) *Human settlement in Switzerland: spatial development and housing.* Granges: Swiss Federal Housing Office.

Hoesli, M (1993) *Investissement immobilier et diversification de portefeuille*. Paris: Economica.

Kemeny, J (1995) *From public housing to the social market: rental policy strategies in comparative perspective.* London: Routledge.

Kemeny, J, Kersloot, J and Thalmann, P (2005) Non-profit housing influencing, leading and dominating the unitary rental market: three case studies. *Housing Studies*, **20**(6), 855–72.

Kenny, G (2003) Asymmetric adjustment costs and the dynamics of housing supply. *Economic Modelling*, **20**(6), 1097–112.

Lawrence, R J (1996) Switzerland. *In*: P Balchin (Ed.) *Housing policy in Europe*. London: Routledge.

Scanlon, K and Whitehead, C M E (2006) The economic rationality of landlords. Paper presented at Meeting of the Housing Economics Workshop, European Network for Housing Research, Copenhagen Business School, Denmark.

Schüssler, R and Thalmann, P (2005) *Qu'est-ce qui pousse ou freine la construction de logements? Résultats d'une enquête menée auprès des promoteurs et des investisseurs immobiliers*. Granges: Office Fédéral du Logement.

Skifter Andersen, H (1998) Motives for investments in housing rehabilitation among private landlords under rent control. *Housing Studies*, **13**(2), 177–200.

Thalmann, P (1997) Housing policy towards ownership in Switzerland. *In*: P Bacchetta and W Wasserfallen (Eds.) *Economic policy in Switzerland*. Basingstoke, UK: Macmillan.

Werczberger, E (1997) Home ownership and rent control in Switzerland. *Housing Studies*, **12**(3), 337–53.

TORNADO SHELTERS AND THE HOUSING MARKET

Kevin M. Simmons[1] and Daniel Sutter[2]

[1] Department of Economics, Austin College, 900 N. Grand Avenue, Suite 61591, Sherman, TX 75090-4444, USA
[2]Department of Economics and Finance, University of Texas - Pan American, Edinburg, TX 78541-2999, USA

Mitigation against natural hazards often involves long-lived, immobile investments. Homeowners must be able to capture the present value of future benefits to equate the private and societal return on mitigation. The capitalization of mitigation into home prices thus is crucial for homeowners to have a proper incentive for mitigation. We investigate the existence of a premium for tornado shelters using home sales in Oklahoma City, where the deadly tornado outbreak of 3 May 1999 and the Oklahoma Saferoom Initiative increased public awareness of tornado shelters. We find that a shelter increases the sales price of a home by 3.5% to 4% or approximately $4200 given the mean price of homes sold in 2005. The magnitude of the premium is plausible given that shelters retail for $2500–$3000 installed.

Keywords: natural disasters, prices, tornado shelters, mitigation, multiple regression.

INTRODUCTION

Natural hazards threaten people and property. While commonly described as “Acts of God,” the choices people make about where and how to live - the built environment - significantly affect natural hazards’ impact on society (Mileti 1999). Numerous measures can reduce the impact of hazards, from the standpoint of economic efficiency; society should invest in the level of mitigation that minimizes the sum of hazard costs plus mitigation costs. Many scholars suggest that society undertakes too little (or an inefficiently low level) of mitigation. A recent analysis found that the benefit-cost ratio of Federal Emergency Management Agency (FEMA) mitigation exceeded four to one (Multihazard Mitigation Council 2005), suggesting (but not proving) that additional investment in mitigation would have yielded net benefits.

We examine one specific mitigation measure in this paper, tornado shelters. Tornadoes are nature’s most violent storm, and particularly prevalent in the Great Plains’ “Tornado Alley”. Storm cellars have a long history in the area, but engineers over the past 30 years have developed new underground tornado shelters and above-ground safe rooms capable of withstanding the most powerful tornadoes. In the 1990s, FEMA included tornado shelters in its National Mitigation Strategy and issued design standards for shelters and safe rooms (FEMA 1999).

Tornado shelters, like other types of mitigation – strengthened construction or elevating structures out of a flood plain – require an upfront investment. Builders and homeowners will be reluctant to invest in mitigation if unable to recoup some of the cost in the form of a higher price for a home or building. But will homebuyers care enough about natural hazards to pay extra for mitigation? We test for a house price

[1] ksimmons@austincollege.edu

premium for tornado shelters in single family homes in the Oklahoma County. Oklahoma City affords an excellent opportunity to test for such a premium due to high tornado risk, high public awareness of the risk, and an inventory of homes with shelters. The inventory of shelters is due in part to the Oklahoma Saferoom Initiative, sponsored by FEMA and the State of Oklahoma after the 3 May 1999 tornadoes. The program offered $2,000 rebates for shelter or safe room installation and received more than 14,000 applications and paid out rebates for 6,400 installed shelters. If a price premium exists for tornado shelters anywhere, it should be in Oklahoma.

We analyse county tax assessor records of over 13,000 home sales in the Oklahoma County area in 2005. Over 400 homes, almost 2.5% of the sample, have tornado shelters. Homes with shelters are available in all size and price categories and not only for the rich buying luxury homes. Homebuyers should be able to find a home with a shelter and other desired features as well. A hedonic regression analysis reveals that homes with shelters sell for 3.5 to 4 percent extra than a comparable home without a shelter, a premium of about $4200 for the average priced home.

The remainder of this paper is organized as follows. Section 2 lays out the theoretical issues regarding the market value of mitigation and reviews relevant previous research. Section 3 provides variable definitions and summary statistics. Section 4 examines the characteristics and location of homes with shelters in greater detail. Section 5 presents our regression analysis. Section 6 offers a brief conclusion and directions for future research.

MITIGATION AND HOUSING MARKET: RELEVANT LITERATURE

Like many types of natural hazards mitigation, tornado shelters are a long-lived, immobile form of self-protection (shelters reduce the probability residents are killed or injured in a tornado, but do little to reduce damage and thus are self-protection instead of self-insurance (Ehrlich and Becker 1972)). A safe room is built into a home and cannot be moved, while the cost of digging up and moving an underground shelter is comparable to installing a new shelter. The resident making the installation is unlikely to personally consume all of the protection of the shelter or safe room, which could have a useful life of over 30 years. Residents may consider only the safety benefits during the time they plan to live in the home and ignore the remaining benefits from the shelter. Due to these spillover benefits, society may experience an inefficiently low level of investment in tornado protection (Kunreuther and Kleffner 1992).

This time horizon problem can be overcome if the shelter purchaser can sell the home at a premium reflecting the value of remaining safety benefits. The homeowner can then capture the full benefit to society of the shelter and can compare the benefits during the period she expects to live in the home with the net cost of the shelter. Premiums for shelters (and other amenities or a well-maintained home) are crucial to an efficient housing market.

Several problems can complicate the sale of homes with tornado shelters at a premium. A first problem is transactions cost. If only a small percentage of buyers value shelters, matching buyers interested in shelters with homes with shelters may be difficult. In the limit if almost nobody valued shelters, they would represent vanity items with no market value. Also buyers interested in a shelter may face a limited range of choices and have to decide between a house with all their desired features except a shelter and a much poorer matched house with a shelter. A poor match with other features reduces the equilibrium premium.

A second problem is buyers ignoring tornado risk altogether in purchasing a home. Many studies have demonstrated the existence of a low probability, high consequence event bias in decision making, people treat the small probability of a tornado or other hazard as zero (Camerer and Kunretuther 1989). When people ignore tornado risk, the perceived value of protection (or mitigation) is zero, even though the same persons might choose to buy a shelter if they perceived the true probability of a tornado. (Note though that Peacock (2003) points out that homebuyers are often quite concerned with hazard risk when looking to buy a home but often lack extra cash after purchase to invest in mitigation.) In addition, some homebuyers will be new to tornado prone areas and consequently unaware of tornado risk in their home purchase decision. Demand for homes with shelters and the market premium falls as the percentage of buyers who ignore tornado risk increases.

Third, potential buyers might exhibit myopia (Kunreuther and Kleffner 1992). Mitigation typically involves upfront expenditure and produces benefits over the useful life of the measure. Myopic individuals focus on the initial cost (or apply too high of a discount rate) and choose not to invest in mitigation measures which seem to have positive expected value. Thus, homebuyers may see the higher price of a home with a shelter and excessively discount the benefits. Kunreuther (1998) argues that financing mitigation through a mortgage or home improvement loan should offset myopia since people can compare the annualized cost with the annual benefit. Since a premium for an existing shelter is included in the sale price of the home and can be financed in the mortgage, myopia may not be a severe problem for tornado shelters.

Economists have estimated hedonic models of home prices for many decades. The technique has been employed, for example, to confirm the impact of environmental factors like air and noise pollution on home prices. Most applications with respect to natural hazards have investigated the impact of risk or risk perception on home prices as a test for low probability event bias. For example, Brookshire *et al*. (1985) and Beron *et al*. (1997) found that homes in seismic zones designated by the state of California sell at a discount, and that the size of the discount declined after the 1989 Loma Prieta earthquake. Shilling *et al*. (1985), MacDonald *et al*. (1987) and Spreyer and Ragas (1991) all found that homes located in flood plains in three different Louisiana cities sold at approximately a 6% discount relative to homes out of the flood plain. Hallstrom and Smith (2005) and Carbone *et al*. (2006) examined the impact of Hurricane Andrew on home prices in two Florida counties, Miami-Dade and Lee. The growth in house prices declined after Andrew in areas of each county most susceptible of storm surge flooding, consistent with a greater perceived risk of hurricanes throughout the state. In all cases, these studies found that participants in the housing market were aware of and responded to the natural hazard risk. Relatedly, Ewing *et al*. (2007) found that powerful tornadoes and hurricanes lowered a housing price index in the affected metropolitan area by 0.5% to 2% in the quarter of the event, but have no permanent effect on house prices. Thus, both natural hazards risk and hazard events can affect home prices, although none of these studies examined mitigation of homes facing a hazard risk directly (restricting building in or relocating homes out of a flood plain is a type of mitigation).

Two studies have applied hedonic price models to examine whether housing markets value natural hazards mitigation. Simmons, Kruse and Smith (2002) found a statistically significant 5% price premium for houses with hurricane blinds in a Texas Gulf coast city. The price premium approximately covered the full cost of hurricane blinds for the average home in their sample. Simmons and Sutter (2007) found a 5% premium in lot rents for tornado shelters in manufactured home parks in Oklahoma. For the average park in their sample, the rent premium would approximately cover the cost of an underground shelter. Their result, however, just failed to attain statistical significance.

Several studies have examined the value of shelters in tornado prone areas, which affects the likelihood of detecting a house price premium. Simmons and Sutter (2006) find that the cost per life saved for tornado shelters in Oklahoma exceeds $50 million (the calculation assumes a 3% discount rate, $2,000 cost per shelter, and a 50 year useful life of a shelter), while market revealed values of a statistical life rarely exceed $10 million (Viscusi *et al*. 2000). This suggests that with full information about tornado risks relatively few households will be willing to pay very much for shelters, leading to the transactions costs problems discussed above in matching the small proportion of home buyers interested in shelters with the small proportion of homes with shelters. Two studies have directly estimated the value of shelters using the contingent valuation method. Ozdemir (2005) in a survey of residents of Lubbock, Texas found that the mean willingness to pay for shelters was $2449, while Ewing and Kruse (2006) found a mean willingness to pay of $2500 in a survey of Parade of Homes visitors in Tulsa. Willingness to pay reflects residents' subjective perception of tornado risk and preferences toward risk, while Simmons and Sutter's cost per life saved uses an objective measure of risk – actual tornado fatalities. Buyers' actual willingness to pay will drive the market premium for shelters, so we may find a market premium even though objective risk data suggests that the premium is likely to be small.

VARIABLE DEFINITIONS

Our data set consists of sales of single-family homes in 2005 in Oklahoma county in the Oklahoma City metro area. We omitted properties with areas of less than 700 square feet or a sales price of less than $10 per square foot, and one home that sold for over $11 million, or more than three times the price of the next most expensive home. We have a data set of 13,461 home sales. The sales data for each county are from publicly available Tax Assessor records. Our data set is cross-sectional and thus unfortunately does not allow analysis of repeat sales of the same property, which would control for immeasurable characteristics of the homes.

Our variable of interest is *Shelter*, a dummy variable that equals one if a home has a tornado shelter or safe room and zero otherwise. Local officials and emergency managers in each county have created an inventory of tornado shelters over the past several years. The inventory combines building permits, rebates awarded as part of the Oklahoma Saferoom Initiative, a property tax exemption for shelters passed by voters in a referendum in November 2002, and self-registration by home owners with emergency managers. The inventories are considered reasonably complete and include the date of installation if a building permit was issued. (For shelters installed during 2005, the date of installation was compared with the sales date to determine if shelter installation preceded the sale. The inventories of shelters distinguish between shelters and safe rooms, but there were too few safe rooms to investigate a separate effect of shelters and safe rooms. Data were also obtained for Cleveland County in the Oklahoma City metro area, but the inventory of tornado shelters appeared quite incomplete (only 6 of over 5,000 homes sold in 2005 were reported to have shelters), and thus we estimated the models using only the Oklahoma County data.)

The dependent variable is the natural logarithm of *Sales Price*, the price in dollars. We employ White's robust standard errors in our regression. Table 1 reports summary statistics for our data set. The average sales price was $119,400, with a range of $8,000 to $3.1 million. Just over of half the homes in the data set sold for less than $100,000, while 11% sold for over $200,000. Figures 1 and 2 display the distribution of home sales prices for all the homes and for homes with shelters.

Table 1: Summary statistics

	Mean	**Standard Deviation**	**Minimum**	**Maximum**
Sale Price	119,362	109,780	8,000	3,100,000
Shelter	0.0297	0.1697	0	1
Square Feet	1,623	759	700	13,395
Age	38.8	23.0	0	145
Masonry	0.7535	0.4310	0	1
Asbestos	0.0298	0.1699	0	1
Brick Veneer	0.0292	0.1683	0	1
Hardboard	0.0147	0.1205	0	1
Siding	0.0705	0.2560	0	1
Vinyl	0.0833	0.2763	0	1
Other	0.0191	0.1367	0	1
Hip	0.2410	0.4277	0	1
Gable	0.4824	0.4997	0	1
Hip/Gable	0.2696	0.4437	0	1
Other Roof	0.0070	0.0832	0	1
Rooms	5.92	1.3950	2	16
Bedrooms	2.96	0.6670	1	8
Baths	1.74	0.6857	1	7.5

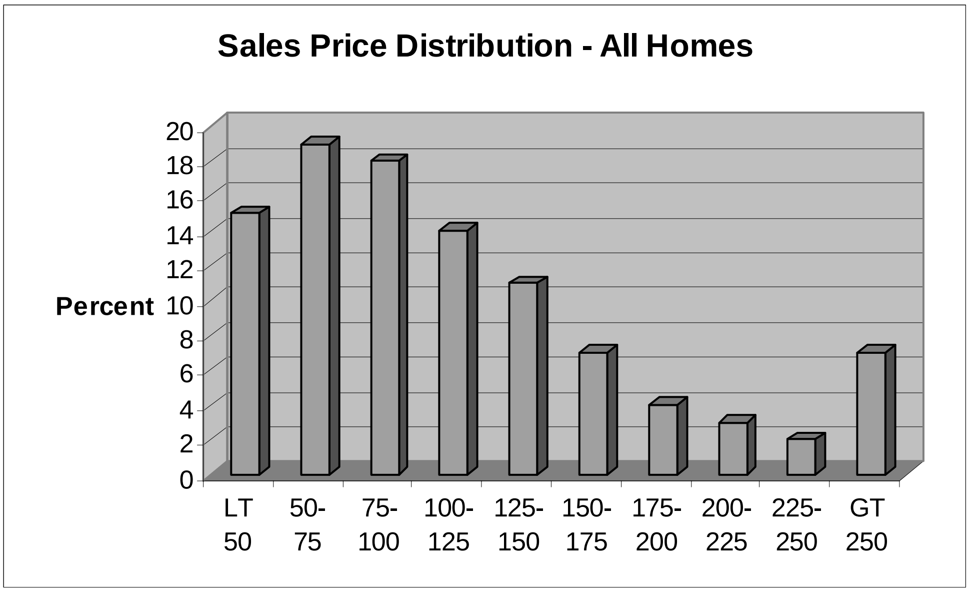


Figure 1: Sales price distributions of homes

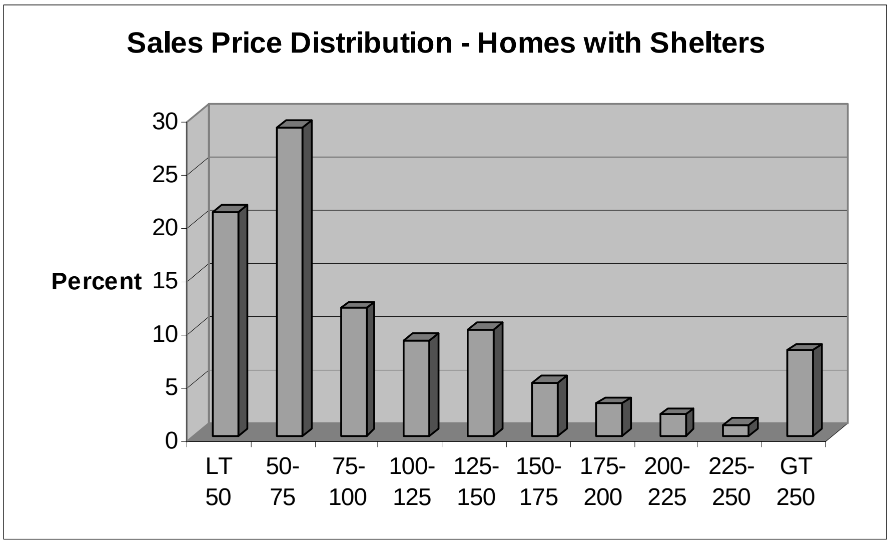


Figure 2: Sales price distribution of homes with tornado shelters

We employ numerous control variables constructed from the Tax Assessor's records. Our basic model for the control variables follows Simmons *et al*. (2002), limited by the exact home characteristics tracked by the Oklahoma County Tax Assessor. *Age* is the age of the home in years in 2005, or 2005 minus the year the home was built. The oldest home in our sample was built in 1860 while 548 homes were built in 2005. The mean age of homes is 38.8, or the average home was built in 1967. About 20% of homes are 10 years old or less, while 28% of homes are over 50 years old. We expect older homes to sell for less, everything else equal (we replace zero with .001 when taking the natural log of *Age*). *Square Feet* is the size of the home. Our mean home size is 1620, with a range from 700 to 13,395. We expect larger homes to sell for a higher price. In addition to *Square Feet*, the Tax Assessor records report three attributes of home size, *Rooms, Bedrooms* and *Baths*. While these variables are all positively correlated with each other and home size. Given the correlation between the variables, we include only *Baths* in our regression.

Our data set contains seven dummy variables describing a home's exterior and four dummy variables describing the roof. The exterior variables are *Asbestos, Brick-Veneer, Hardboard, Masonry, Siding, Vinyl* and *Other Exterior*, while the roof variables are *Hip, Gable, Hip/Gable* and *Other Roof.* All of these variables were constructed by the authors from the Tax Assessor records. We omit *Masonry* and *Hip* in our regressions, so the coefficients on the included variables show the effect of each exterior or roof type relative to these categories. We have no expectations about the signs of these variables, which we include as controls.

We include a number of dummy variables to control for location. About 65% of homes sold in 2005 were in Oklahoma City, so we include a dummy variable *OKC* equal to one for homes in Oklahoma City and zero otherwise. We also define a set of zip code dummy variables for each of the 51 zip codes included in our data set. These variables should control for differences in local neighbourhood housing markets. In addition, we include a set of dummy variables for the month of sale of the home. Both the zip code and month dummy variables were jointly significant, but to conserve space we do not report them in our regression tables.

A CLOSER LOOK AT HOMES WITH TORNADO SHELTERS

Before turning to our econometric analysis, we first examine the characteristics of homes with tornado shelters in some detail. A problem for our empirical analysis would arise if only large, expensive, new homes had shelters. In this case, a shelter premium could actually be a premium for luxury homes, particularly if our control variables fail to adequately capture the features of upscale homes. The distribution of shelters across types of homes also affects societal vulnerability (Peacock 2003). If tornado shelters were only available in half million dollar, 4000 square foot homes, few people could afford a house with a shelter, and policy makers might consider taking steps to make shelters available for working class families.

Table 2 presents the mean values of several variables for homes with shelters. The table also indicates if the mean significantly differs from the population mean. A simple mean comparison shows no evidence of a price premium for shelters, as the mean sales price for homes with shelters is $109,000, compared with $119,000 for all 2005 home sales, a difference that is statistically significant at the 10% level. The comparison certainly indicates that some average and below average priced homes have shelters. Closer analysis shows that 21% and 41% of homes with shelters sold for under $50,000 and between $50,000 and $100,000 respectively compared with only 15% and 37% of all home sales in these price ranges. Clearly, buyers in all price ranges can find homes with tornado shelters.

Table 2: Characteristics of homes with shelters

	Mean	Standard Deviation	Minimum	Maximum
Sale Price	108,791	96,326	12,500	635,000
Shelter	1	0	1	1
Square Feet	1,484	753	700	4,917
Age	41.9	22.5	0	100
Masonry	0.6123	0.4878	0	1
Asbestos	0.0617	0.2410	0	1
Brick Veneer	0.0272	0.1628	0	1
Hardboard	0.0247	0.1554	0	1
Siding	0.0914	0.2885	0	1
Vinyl	0.1679	0.3742	0	1
Other	0.0148	0.1210	0	1
Hip	0.2494	0.4332	0	1
Gable	0.5012	0.5006	0	1
Hip/Gable	0.2444	0.4303	0	1
Other Roof	0.0049	0.0702	0	1
Rooms	5.72	1.3616	2	10
Bedrooms	2.84	0.6759	1	5
Baths	1.58	0.7174	1	4.25

We might expect that only large, new homes would have tornado shelters, but Table 2 shows this is not true. Homes with shelters were on average three years older and 140ft^2 smaller than all homes sold in 2005. Again analysis of the distribution of homes by size and age confirms that a wide variety of homes feature shelters. Thirty percent of homes with shelters were less than 1000ft^2 and only 17% over 2000ft^2, while 19% and 23% of all homes sold fell into these categories. A total of 43% of homes with shelters were over 50 years old compared with only 32% of all homes sold. (The age of many of the homes with shelters raises the possibility that these older homes have unfinished basements or storm cellars and not modern shelters or safe rooms. The inventory of shelters does not control for quality or include only shelters built to

FEMA specifications. Ewing and Kruse (2006) find that people would be willing to pay $600 extra for shelters certified by the National Storm Shelter Association; we will control for old homes in our econometric analysis.)

Table 2 also reports the mean values of the room, exterior and roof variables for homes with shelters. Comparison reveals that homes with shelters have fewer *Rooms*, *Bedrooms* and *Baths* than the sample as a whole, with the differences being statistically significant at the 1% level. Homes with each category of interior and roof have shelters, so buyers should not have to sacrifice too many desired characteristics to buy a home with a shelter.

As mentioned above, almost all the homes with shelters in our sample were located in Oklahoma County. Overall, about 3% of homes sold in Oklahoma County had shelters. Our data set includes homes in 11 different cities within the county. The percentage of homes sold with shelters ranged across communities from 1.8% in Edmond to 6.9% in Del City, which was affected by the 3 May 1999 tornado and where many residents took advantage of the Oklahoma Saferoom Initiative. Homes with shelters are available throughout the county, so a buyer should be able to find a home with a shelter near their desired placed to live.

RESULTS

Table 3 reports our regression results. Column (a) contains the full model estimated on our entire data set. Our variable of interest, *Shelter*, has a positive point estimate, indicating a 3.5% price premium, and is statistically significant at the 10% level in a two-tailed test. The 3.5% price premium translates into a $4200 price differential for our average priced home. The magnitude is very reasonable given that underground shelters currently retail for $2500–$3000 installed, while above-ground safe rooms cost $5,000 or more. Note that this amount exceeds by about 67% the mean willingness to pay for a shelter or safe room of $2500 found by Ozdemir (2005) and Ewing and Kruse (2006).

Square Feet and *Age* perform as expected, with larger and newer homes selling for a higher price and both variables significant at better than the 1% level. Both of these variables enter in logs in our specification, and thus the coefficients are elasticities. Specification (a) shows that a 10% increase in area increases the sales price by about 9%, while a 100% increase in *Age*, say from one to two years, reduces price by about 2%. An extra *Bath* increasing the price by about 16%. Homes in Oklahoma City sell at a statistically significant 13% discount relative to the rest of Oklahoma county. Four of the exterior variables are significant at the 10% level or better, while none of the roof variables are significant at the 10% level, so buyers seem to place greater weight on the exterior than the roof.

The majority of homes in our sample are in Oklahoma City, and as a robustness check on our results, we report in (b) a specification of the model using only homes in Oklahoma City. This specification eliminates differences in local government services across jurisdictions, which may be imperfectly controlled for with the zip code dummy variables, as a possible explanation of our results. Note that the model also includes zip code dummy variables to control for neighbourhood effects within Oklahoma City. The point estimate of *Shelter* is a slightly larger 4.2% price premium than in (a). The point estimate fails to attain significance at the 10% level in a two-tailed test, although the estimate is significant at the 10% level in a one-tailed test. Overall the estimated coefficients of the other variables are virtually unchanged, with the only difference in significance that *Siding* is no longer significant, although its point estimate is slightly larger.

We noted earlier that 43% of homes with shelters were over 50 years old, and that some of these older homes might have storm cellars instead of modern shelters. Home buyers might not consider these equivalent to new shelters and safe rooms, and this might affect the estimated shelter premium. We do not know the age of the shelter, and so cannot control for old shelters directly. Consequently, column (c) presents a specification omitting homes over 50 years of age, which should exclude all vintage storm cellars. Omission of old homes has a modest effect on *Shelter*, which is now exhibits a statistically significant at the 10% level in a two-tailed test 4.0% price premium. The price premium for the average priced home is now approximately equal to the cost of an above-ground safe room. A few modest differences between the specifications with the full data set and with old homes are excluded. The coefficient on *Square Feet* is slightly larger with an elasticity now just less than one, while the coefficient on *Age* is reduced, and newer homes in Oklahoma City sell at a discount of just over 4%. *Vinyl* and *HipGable* now attain significance at the 5% level, while the overall fit of the model is slightly reduced (we also estimated the model excluding the 20 homes that sold for more than $1 million, but the results were very similar to (a) and so we do not report this specification here).

Table 3: Regression analysis of home sales price

	Full Specification	**OKC Only**	**Old Houses Excluded**
CONSTANT	4.64***	4.48***	4.37***
	(34.3)	(27.6)	(29.1)
Shelter	.0342*	.0409	.0393*
	(1.80)	(1.52)	(1.69)
LN(Square Feet)	.887***	.881***	.950***
	(49.9)	(40.2)	(49.7)
LN(Age)	-.0179***	-.0205***	-.0121***
	(8.14)	(6.15)	(5.52)
OKC	-.138**		-.0434***
	(11.6)		(3.44)
Asbestos	-.179***	-.204***	-.426***
	(3.98)	(3.49)	(4.48)
Brickveneer	.304***	.402***	.0821*
	(7.71)	(6.94)	(1.86)
Hardboard	-.0529	-.0760	-.178***
	(0.99)	(1.08)	(3.04)
Masonry	.142***	.213***	-.0650
	(3.91)	(4.31)	(1.54)
Siding	-.0705*	-.0729	-.0957**
	(1.77)	(1.37)	(2.03)
Vinyl	.0133	.0163	-.126**
	(0.34)	(0.31)	(2.44)
Hip	.0384	.0211	.0817
	(0.73)	(0.37)	(1.44)
Gable	-.0126	-.0391	.0453
	(0.24)	(0.68)	(0.80)
HipGable	.0486	.0132	.118**
	(0.92)	(.023)	(2.09)
Baths	.158***	.174***	.126***
	(14.6)	(12.2)	(11.0)
Adjusted R^2	.732	.684	.769
# Observations	13,641	8679	9219

Absolute t-statistics based on robust standard errors in parentheses. *, ** and *** indicate significance at the .10, .05 and .01 levels respectively in a two-tailed test. Each model also includes zip code and sales month dummy variables.

CONCLUSION

The 2004 and 2005 hurricane seasons increased public interest in mitigation measures capable of reducing losses from natural hazards. Mitigation often involves a long-lived, immobile investment. Homeowners who invest in mitigation may not capture all of the benefits of mitigation if they do not live in the home throughout the measure's useful life. House price premiums for mitigation must exist for the market to provide proper incentives for investment in mitigation.

We have investigated the existence of a premium for tornado shelters in the prices of homes in the Oklahoma City metro area in 2005. Consistent with Simmons *et al*. (2002) for hurricane shelters, we found a premium for tornado shelters. The *Shelter* variable is statistically significant at only the 10% level, although this would be at the 5% level in a one-tailed test, which would be appropriate if we did not expect that *Shelter* could reduce the sale price. The point estimate indicates a $4200 shelter premium for the average priced home in our sample, which exceeds the cost of underground shelters but is somewhat less than the cost of above-ground safe rooms.

One direction for future research would be a longitudinal study involving repeat sales of homes. Repeat sales analysis focuses on the change in price, and this avoids problems with unchanging but hard to measure factors affecting home prices (Hallstrom and Smith 2005; Carbonne *et al*. 2006). If repeat sales of homes before and after shelter installation can be identified, this would allow determination of whether a price increase can be attributed to the shelter.

Future research could also search for shelter *premia* in other real estate markets. Several factors made Oklahoma City particularly likely to exhibit a premium for tornado shelters: a high risk of damaging tornadoes, high public awareness of tornado risk and a sufficient inventory of homes with shelters. It may be unlikely to find a premium for shelters in other cities because the cost per life saved for tornado shelters in single family homes increases quickly even when comparing tornado prone states like Oklahoma and Texas (Simmons and Sutter 2006b). However, along the Gulf coast or in Florida, shelters and safe rooms also provide protection against hurricane winds as well, so safe rooms might carry a premium due to dual use in these areas.

REFERENCES

Beron, K J, Murdoch, J C, Thayer, M A and Vijverberg, W P M (1997) An Analysis of the Housing Market Before and After the 1989 Loma Prieta Earthquake. *Land Economics*, **73**, 101–13.

Brookshire, D S, Thayer, M A, Tschirhart, J and Schulze, W D (1985) A Test of the Expected Utility Model: Evidence from Earthquake Risks. *Journal of Political Economy*, **93**, 369–89.

Camerer, C and Kunreuther, H (1989) Decision Processes for Low Probability Events: Policy Implications. *Journal of Policy Analysis and Management*, **8**, 565–92.

Carbone, J C, Hallstrom, D G and Smith, V K (2006) Can Natural Experiments Measure Behavioral Responses to Environmental Risks? *Environmental and Resource Economics*, **33**(3), 273–92.

Ehrlich, I and Becker, G S (1972) Market Insurance, Self-Insurance, and Self-Protection. *Journal of Political Economy*, **80**(4), 623–48.

Ewing, B T and Kruse, J B (2006) Valuing Self Protection: Income and Certification Effects for Safe Rooms. *Construction Management and Economics*, 24(10):1057-1068.

Ewing, B T, Kruse, J B and Wang, Y (2007) Local Housing Price Index Analysis in Wind-Disaster-Prone Areas. *Natural Hazards*, **40**(2), 463–83.

Federal Emergency Management Agency (1999) *Taking Shelter from the Storm: Building a Safe Room Inside Your House*. FEMA publication #320, 2ed.

Hallstrom, D G and Smith, V K (2005) Market Responses to Hurricanes. *Journal of Environmental Economics and Management*, **50**(3), 541–61.

Kunreuther, H (1998) A Program for Reducing Disaster Losses through Insurance. *In:* H Kunreuther and R J Roth Jr (Eds.) *Paying the Price*. Washington DC: Joseph Henry Press.

Kunreuther, H and Kleffner, A (1992) Should Earthquake Mitigation Measures be Voluntary or Required? *Journal of Regulatory Economics*, **4**, 321–35.

MacDonald, D N, Murdock, J C and White, H L (1987) Uncertain Hazards, Insurance, and Consumer Choice: Evidence from Housing Markets. *Land Economics*, **63**, 361–71.

Mileti, D S (1999) *Disasters by Design*. Washington DC: Joseph Henry Press.

Multihazard Mitigation Council. (2005) *Natural Hazard Mitigation Saves Lives: An Independent Study to Assess the Future Savings from Mitigation Activities*. 2 Volumes. Washington DC: National Institute of Building Sciences.

Ozdemir, O. (2005) Risk Perception and the Value of Safe Rooms as a Protective Measure from Tornadoes: A Survey Method. *In:* B T Ewing and J B Kruse (Eds.) *Economics and Wind*. Nova Science Publishing.

Peacock, W G (2003) Hurricane Mitigation Status and Factors Influencing Mitigation Status among Florida's Single-Family Homeowners. *Natural Hazards Review*, **4**(3), 149–58.

Shilling, J D, Benjamin, J D and Sirmans., C F (1985) Adjusting Comparable Sales for Floodplain Location. *Appraisal Journal*, **53**, 429–36.

Simmons, K M, Kruse, J B and Smith, D A (2002) Valuing Mitigation: Real Estate Market Response to Hurricane Loss Reduction Measures. *Southern Economic Journal*, **68**(3), 660–71.

Simmons, K M and Sutter, D (2006) Direct Estimation of the Cost Effectiveness of Tornado Shelters. *Risk Analysis*, **26**(4), 945–54.

Simmons, K M and Sutter, D (2007) Tornado Shelters and the Manufactured Home Market. *Natural Hazards*, forthcoming.

Spreyer, J F and Ragas, W R (1991) Housing Prices and Flood Risk: An Examination Using Spline Regression. *Journal of Real Estate Finance and Economics*, **4**, 395-407.

Viscusi, W K, Vernon, J M and Harrington, J E Jr (2000) *Economics of Regulation and Antitrust*. 3Ed. Cambridge, MA: MIT Press.

SOCIAL SCIENCE RESEARCH AND CONSTRUCTION: BALANCING RIGOUR AND RELEVANCE

Chris Harty[1] and Roine Leiringer

School of Construction Management and Engineering, University of Reading, PO Box 219, Reading, RG6 6AW, UK

For construction management (CM) research, the challenge of linking academic research priorities with those of industry, and to generate the flow of knowledge between the two is crucial. It is also not straightforward. Here, the debate over academic rigour versus industry relevance, or bridging the 'relevance gap' is discussed specifically with respect to CM social science oriented research. We argue that the relationship between the two is complex, and to position them as polar opposites is a misleading oversimplification. We identify other actors and institutions which also influence the generation of research questions and outputs. The argument is made that the landscapes of academia and industry are reflexively and recursively linked rather than separate and distinct, especially in an applied field such as CM. It is through exploring these connections and interactions and the practices and ideas which emerge from them that relevance and rigour can be best understood.

Keywords: relevance, research methods, rigour, social science.

INTRODUCTION

Across much social science research, including construction management and management more generally, the challenge of linking academic research priorities with those of industry, and to generate the flow of knowledge between the two is considered crucial. Academic research uses real world contexts as sites for both developing research questions and conducting empirical study to examine them. In return for such access, researchers make claims that research outputs will have utility outside academic domains. Without such promises of exchange, the relationship between research and industry becomes essentially parasitic, which does little to develop good relations between the two. As well as the need for reciprocal relationships, developing effective connections between academia and industry is prioritized at the highest levels. The 1993 government White Paper *Realising our potential: a strategy for science engineering and technology* called for

> closer partnership and better diffusion of ideas between the sciences and engineering communities, industries, the financial sector and Government … as past of the crucial effort to improve our national competitiveness and quality of life (HMSO 1993: 8).

But although the rhetoric of users and industry collaboration permeates construction management funding priorities calls and proposals, relationships between academia and industry are beset with difficulties. HEFCE, in their *Industry–academic links*

---

[1] c.f.harty@reading.ac.uk

report (Howells *et al.* 1998) outline some of the ways that these manifest themselves. Among other things the report contends that:

- although industrial actors believe that research can be beneficial, few research topics are seen as focusing on key issues of relevance to them;
- managers feel that research does not directly contribute to their activities. In order to do so, prescriptive statements and best practices which can be implemented are wanted, over reflexive analysis;
- industrial sectors lack awareness of research and research results. Researchers lack effective methods to disseminate results.

These statements imply the existence of significant differences between academic and business contexts, that interests do not overlap and that no effective means or mechanisms of knowledge sharing are evident. It is therefore not surprising that the highest ranked barriers to higher education institutions producing effective links with industry were identified as ‘differences in objectives’ and ‘work needed by industry not interesting’.

The HEFCE report is not in isolation in drawing these kinds of conclusions. Similar findings and views aired elsewhere have prompted a debate within management literature of how to satisfy the double hurdles of being relevant to industry and maintaining academic rigour, or of bridging the ‘relevance gap’ between the two.

The debate is not just about finding a median point between the ivory towers of academia and the hard-nosed world of business. It includes a number of issues such as: the extent to which research should act as a problem-solving ‘service’ to business sectors; the importance of research being disconnected from current business concerns in order to develop novel ideas, processes and products; alternative ways businesses might generate relevant knowledge; and, importantly, the different sorts of epistemological positions being implied.

We contend here that a major stumbling block in attempting to understand the relationship between relevance and rigour is falling into an easy opposition between business and academic worlds. This assumes that there is a clear-cut distinction between the two, and that each is a homogeneous entity with recognizable similarities and shared priorities. This is, of course, far from the reality of the situation where researchers must continually satisfy a number of different bodies if they are to ‘do’ relevant and rigorous research. These include academic peers, funding bodies and industrial partners, each of which has their own priorities, peculiarities and paymasters. Much can be made of the rhetorical aspects of, for instance, convincing funders that research effectively reflects and addresses non-academic priorities, or in enrolling industrial partners with promises of relevance, while continuing to pursue mainly academic priorities. However, as well as reproducing the notion of a relevance gap this strategy would also seem to be unsustainable in the longer term, especially in the sense of keeping industrial partners interested and involved. A question that remains unanswered is what actually counts as useful research within these different domains?

This paper explores these issues, drawing on wider management and social science literatures but in relation to social science oriented UK construction management research. The aim is to illuminate some of the key interactions that constitute CM research, which incorporates numerous academic and industry actors. To begin, the polarization of relevance and rigour is questioned and evidence for the overlapping or merging of industry and academic terrains is discussed. The notion of 'playing the game' of relevance and rigour is explored, as are the relationships between research and enterprise and research and teaching within university institutions. The different epistemological lenses mobilized and forms of knowledge required and produced by different actors are discussed, including the distinctions between Mode 1 and Mode 2 knowledge production. A case is made for seeing academic and industry domains as reflexively linked, not distinct and separated by any relevance gap.

RELEVANCE AND RIGOUR IN CONSTRUCTION MANAGEMENT RESEARCH

Within CM as well as more widely, the academic rigour of research has largely been shown through publishing in refereed journals. The reviewing and refereeing process, undertaken by academic peers, ensures that what gets through demonstrates the required level of scholarly content. It traditionally operates in parallel with any industry or policy oriented report writing and dissemination that research projects generate. However, this seems to be changing, and there is evidence that relevance and rigour cannot be sustained as contrasting aims. Within construction publications, McCaffer (2007) recognizes that there is a clear trend towards demands of demonstrating research's impact upon industry. He states:

> the issue is if research has no impact (and I don't mean citations) then what is it worth. [sic] ECAM [Engineering, Construction and Architectural Management] should lead the field in asking authors to address the impact of their research more than we have. In effect academics are responsible for the implementation of their research and must be seen to be succeeding in this (McCaffer 2007).

McCaffer, then, suggests that the fundamental criteria of a good refereed paper are shifting towards its impact on industry. What is clear is that the notion of impact further serves only to muddy the waters of relevance and rigour. A relevance gap allows researchers to align their research around two distinct poles; one regarding its relevance and one regarding its rigour. This might be somewhat difficult to achieve in practice, but offers clear targets, if nothing else. A shift towards impact on industry as a mark of an academic paper's quality conflates these two positions. What does this mean for the rigour of construction research and research papers? How can their relevance be academically demonstrated? Without the convenience of a polar opposition between relevance and rigour the job seems even more difficult.

We might also ask who the ultimate beneficiaries of research are supposed to be. Relevant research could benefit individuals, single firms, sectors, 'industry' as a whole, 'the economy' or 'society' more generally. It is therefore problematic to conceptualize the directions of the research and the beneficiaries thereof as unidirectional or asymmetrical. The term 'impact' thus lends itself to a significant degree of subjective interpretation. A strong idealistic case could be made for the need of judging what research is deemed useful to society to be collectively determined rather than basing it on its impact on the specific business interests of companies. In contrast, it is tempting to follow the path of least resistance and comply with external pressures, aligning research with business priorities.

There is no doubt that CM researchers are sensitive to the larger contexts in which sectors, businesses and other institutions such as universities and research councils operate and how research is positioned within them. The UK construction sector has a long history of reviews which bemoan its performance and reports and policy documents prescribing change are constantly circulated throughout industry and academia. Over the past decade or more such a change agenda has been determined by an incessant mantra of modernization (cf. Fernie *et al*. 2006). Reproduced and supported by government and industry leaders it constantly reiterates the notion that research in the construction domain is only valid if it is industry centred and driven by the need for change. Riding along on this undercurrent comes a plethora of fads and fashions which, although viewed with some scepticism by many academics, have a great deal of currency within business contexts. It becomes rather tempting for researchers to position their research within this popular mantra for change, and to have recourse to such fads and fashions as are current at a particular time. Such compliance at times might come at the expense of the rigour of such approaches. Furthermore, it fails to acknowledge or discuss the implications of academic research offering advantage to one constituency at the expense of another.

It is necessary to keep in perspective that some of the statements made above are generalizations and run the risk of being overly simplistic. It would, for example, be naïve to state that CM researchers share the same ideas about the sort of product that their work generates, its effects on policy and practice and indeed how it contributes to knowledge. Such differences between researchers have led to a variety of distinctions being drawn between various approaches to research.

One important distinction is that between rational–instrumental modes of research rooted in the sciences and ‘pure’ engineering, and more subjective and qualitative approaches to construction management appropriated from disciplines such as sociology. The former ‘engineering model’ positions research as revealing something ‘true’ about the world it focuses on. This goes equally for research on the strength of particular materials as it does for economic modelling of construction processes. The intention is that by revealing something of reality, tools to help can be developed and implemented to predict, improve or exploit it. These might be in the form of stronger reinforcement materials, ‘best practice’ advice or new IT systems for managing workers. In terms of social science research in this tradition the findings are considered to be widely applicable in relatively predictable ways with identifiable and beneficial results.

By contrast, the latter more subjectivist approaches eschew the notion of a single objective reality in favour of seeking to understand how different realities and perspectives are locally constituted. This sort of research is interested in how meaning and values are derived, and how interactions between actors and material artefacts develop as they occur, and the practices and ideas that emerge from them. Any claims for the utility and applicability of knowledge or insights generated from this type of research would tend to be more modest than those within the harder engineering paradigm, with little expectation of wide generalizability or easily transferable results. This means that claims of relevance and impact on industry become more difficult to assess.

As an applied field construction management is populated by researchers subscribing to both of these approaches. This is obviously a positive quality, but can lead to attempts to judge more subjective research with harder measures. The relevance of a best practice guide is easy to ascribe if the engineering perspective is the one taken; judging its relevance from a more critical perspective entails a more involved discussion of the sorts of contexts in which research-generated knowledge has to make sense.

PLAYING THE RESEARCH GAME

One way to approach relevance and rigour is to think about the undertaking of research as playing a game with numerous different parties involved. It seems eminently sensible to suggest that academics routinely wear different hats in order to engage with different audiences. However, in order to do this, research must inherently have a certain amount of ‘interpretive flexibility’ (cf. Bijker 1992) to allow it to be shaped or mutated in different ways according to its intended audiences. Following from this, beneath this flexibility must lie core research activities which represent the real and autonomous interests of researchers. Questions then arise of precisely how much flexibility the ‘core’ research inherently has and to what extent the shaping of research ideas can be separated from the research process itself. It is possible that in attempting to satisfy multiple audiences, the research itself becomes somewhat diluted or stretched, and thereby loses or changes its focus. This has been highlighted at an institutional level by Elzinga (1985) as ‘epistemic drift’. As the priorities of academic institutions shift in responding to new external pressures, for instance demands from government to engage more with industry or to demonstrate the non-academic relevance of research, so too do their research agendas and research processes.

This drift is positioned by Elzinga as a watering down of the academic content of research and as constituting a change in the nature of the research being produced. The underlying argument that academic research should not be influenced by non-academic pressures might, however, be both misleading and misguided. Pure academic research with no connection or influence to any external factor is probably nothing short of a fiction. For good or ill, non-academic priorities do influence research agendas and activities. Through the wearing of different hats, the ideas and activities of the wearer are transformed.

Breslau (1997) offers a complementary perspective and proposes that it is perhaps more useful to look at how recognition is gained in contrasting social arenas, rather than looking at the outputs produced by research. He refers to Bourdieu’s (1986) concept of ‘capital’ and to the suggestion that individuals work to amass various forms of capital (e.g. economic, cultural, etc.), which have significance within different fields. Breslau develops the idea that ‘credibility’ constitutes one such form of social capital within business and academic domains. For research to be relevant and academically sound, it needs to be credible in both locations. The problem is that the mechanisms through which credibility is endowed are not the same in each. Within the academic field, established reputational sources of credibility are underpinned by a disciplinary structuring of knowledge and peer review. As such academia revolves around a number of more or less internally consistent relatively homogenous structures. In contrast, the status of research within the private sector is much more heterogeneous. Credibility is conferred by multiple external groups, including advisory panels, research funders, industry spokespersons and practitioners. In business (broadly defined), credibility comes from the practical (and non-academic) implications of research, and from its utility as a resource for controlling, influencing or understanding business contexts. The problem of relevance remains as one of satisfying plural demands, gaining the appropriate credibility in different locations. It is clear that the game that has to be played is different within these different landscapes.

Rooted in social science approaches Breslau then develops these ideas by comparing the ‘purer’ academic approaches of economists, with more ‘hands-on’ and qualitative approaches of sociologists located in ‘contract shops’ outside academia. In general researchers were found to seek to gain credibility in one or other domain but not both. Different strategies were employed in each case; ‘incorporation’ and ‘secession’ (*ibid*.). The strategy of incorporation is one in which research is positioned in relation to existing (disciplinary) knowledge and is judged by academic peers. Secession on the other hand involves rejecting these conventions, and dismissing evaluation by the scholarly community. The focus is instead on the extent to which research is grounded in local contexts and framed by the meanings and assumptions found within them. The ‘contract-shop epistemology’ of the secessionists facilitates a more interactive connection between research and contexts, using localized and qualitative approaches. But the implication is that this is at the expense of disciplinary rigour. Although Breslau highlights the socialized nature of the contexts of research and of the research process itself, his analysis still reproduces a gap between academic and external concerns.

Of particular note is the strong case he makes about the deep entrenchment of discipline-based practices and ways of thinking in the US university economics departments he looked at. This resonates strongly with the ideas of disciplinary structuring through reputation in the UK offered by Whitley (1984) as well as with other work on the problems of positioning and evaluating interdisciplinary knowledge (see Harty and Shove 2004; Shove and Wouters 2005). The calls for interdisciplinary approaches to real world problems made by research funders such as the UK research councils do not juxtapose easily with the disciplinary-based structures of academic assessment through journal publication. These disciplinary-based mechanisms are themselves reproduced by the present methods of the research assessment exercise conducted by those very same institutions calling for interdisciplinary approaches.

PLAYING THE RESEARCH GAME IN CM

The challenges in satisfying numerous demands are also evident in construction management. Yet, it must be noted that UK CM research has a particularly good record for getting research funded and in working with industry. Indeed, many researchers and research institutions pride themselves on developing and maintaining long-term relations. There also seems to be no shortage of academic papers being submitted to CM conferences and journals.

So how are the various sets of requirements and demands handled and played out in practice? The obvious answer is that research ideas and outputs from research activity are framed or shaped differently for different audiences, with each version telling its prospective audience something of what it wants to hear. Proposals are worded in specific ways to resonate with funders’ priorities and expectations; industry-focused documents tend to avoid jargon and be more concise. Papers are written with specific journals in mind, which can dictate not just format, but the positioning of the research, the sorts of literature cited and even the arguments developed. Within all of these, current fashions, hot topics and buzzwords might be used or alluded to as deemed suitable.

However, as well as the problem of drifting (epistemically or otherwise) away from core research interests, this would also invariably produce a certain degree of routinization of efforts. It is plausible to suggest that these means of assessment lead to the emergence of highly scripted approaches and outputs, especially if they have proved successful in the past. Kaplan (1964) discussed 'the law of the instrument'. Give a small boy a hammer, he argued, and he will find that everything that he encounters will need a pounding. While the metaphor is rather crude and it would be wrong to characterize researchers in the field as one-trick ponies, the above-described scenario would seem to generate instrumental approaches which resonate with accepted ideas and ways of forming and formatting research, rather than novel ideas.

Take, for example, the journal outlets available in the field. Many of these have word restrictions of between 3000 and 5000 words. As such it could be argued that they favour papers that are structured along the lines of the engineering model. While many researchers would not openly subscribe to this model they are still coerced to represent their research in this manner as it greatly increases their chances of getting published. Even without any political bias towards one or other method, the length allowed for papers means that, for example, detailed qualitative analysis is difficult to produce as it invariably requires more words to describe than papers based on more generalized and concise outputs. This same problem also applies to outputs oriented to industry. In all it encourages the production of the same sort of outputs over and over again. This has much appeal to the researcher as it generates the accumulation of publications which is crucial to individuals' CVs and appeals to the efficiency-led rationale of much of industry.

So it would appear that the playing of multiple games might adequately describe the activities of researchers, but that it is difficult to separate this from the formulation or transformation of research agendas, activities and outputs. Through concerted efforts to play the game, or through less direct processes like epistemic drift, ideas and outputs are constituted and transformed as they go through processes of funding, researching and publishing.

RESEARCH AND ENTERPRISE

As well as thinking about the different networks that individual researchers inhabit, and the activities they perform in getting funding and doing research, the wider institutional contexts in which they operate should also be considered. Universities are increasingly moving into areas such as spin-off commercialization of research outputs and consultancy. 'Enterprise' has become a key strategic theme – again muddying any waters that might once have reflected a clear divide between academic and non-academic priorities.

This means that in practice, construction management researchers have to sell their ideas (and themselves) to a range of potential customers in competition with other players in turbulent and increasingly overlapping marketplaces. It is not quite so simple as offering distinctive qualities or 'unique selling points' of academic research – which traditionally have tended to be its scholarly rigour; its particular (non-business-based) approach to understanding; and its commitment to long-term knowledge development. If firms subscribe to government opinion as outlined in the *Realising our potential* White Paper and see research output merely as a resource with which to achieve increased competitiveness or solve immediate problems these qualities are likely to have little perceived value. As indicated in the HEFCE report, practitioners seem to prefer knowledge packaged in the form of discrete, manageable chunks, for example as best practice prescriptions. Academic research is just one possible route to new knowledge production with others typically including consultancy, training and using the skills of in-house staff. What do academics really have to offer in these markets?

The solution to this conundrum does not necessarily lie in academic research getting ‘closer’ to the priorities and activities of industry. Many academics in construction management have, indeed, been critical of the overuse of instrumental approaches and an over-reliance on faddish concepts at the expense of substantive change (e.g. Green 1999; Bresnen and Marshall 2000). If some form of ‘contract shop epistemology’ is adopted, this critical function is in danger of being lost. This also potentially moves researchers away from the publication of scholarly papers, which so far has been an essential requirement for the advancement of any academic career. We arrive back at the same problems of incommensurability between academic and non-academic terrains.

RESEARCH AND TEACHING

It is also important to consider that research is not the only, or even the main, activity of universities. Teaching is central to a university’s success, and competition for attracting students is fierce. But this also brings with it inconsistent demands regarding the balance between academic and practitioner focus. Academic teachers and researchers are expected to respond to new and emerging problems and to engage with current non-academic priorities. At the same time, academic institutions are expected to provide a relatively stable platform of knowledge (i.e. textbook learning) in digestible chunks which informs and sometimes even constitutes the activities, problems and contexts of ‘management’ or ‘business’. The success of university institutions is largely governed by the attraction of students, which is itself at least partly a reflection of the employability of graduates with qualifications from specific schools or universities. But according to many managers, this type of teaching does not provide industry with individuals possessing the relevant skills to increase firms’ competitive edge. Higher qualifications such as MBAs have long been berated for lacking in providing transferable skills of use in the outside world (Linder and Smith 1992). Other issues, such as how less instrumental qualities such as entrepreneurship can be taught through devices such as lecturing (usually by non-practitioners) are also being raised (Binks *et al*. 2006).

This suggests that the standard model based on lecturing and written assessment is also failing to bridge the gap between academia and industry, although these opinions do not seem to have affected the demand for undergraduate degrees as a prerequisite for employment, or the bargaining power within industry offered through higher qualifications such as the MBA. So is the primary function of teaching to produce useful (and hence relevant) new construction managers for the industry? If so, where is the dividing line between imparting chunks of directly applicable knowledge through textbook learning, and developing critical (i.e. more academic) skills?

KNOWLEDGE FOR WHOM? THE EPISTEMOLOGICAL PRODUCTS OF RESEARCH

Thinking about the games played by researchers, the contexts in which they play and the consequences of the rules followed identifies a plethora of problems. However, what it does not do is bring us any closer to understanding the (dis)connections between the knowledge produced by academic research and what industry wants and considers useful. One explanation for this can be traced to the different epistemological lenses used by different researchers and by practitioners to frame and understand apparently similar problems and issues. This can culminate in a range of different accounts of the same problem, and ways to approach it.

According to some, firms have a particular lens or way of seeing their contexts which involves being only 'interested in the application of knowledge rather than knowledge for its own sake' (Starkey and Madan 2001: 6). This leads to a somewhat prescriptive-looking 'knowledge chain', designed to resolve specific problems effectively and efficiently through problem identification, data collection, decision making and solution.

This prescriptive view suggests that for academic research agendas to be relevant, they must engage directly with specifically business-oriented ways of framing and applying the knowledge they produce. A shared problem is not enough; research needs to be conducted and presented in ways which allow it to be evaluated by practitioners (decision making) and offer effective ways of implementing its insights (effective action). Neither is this an end-of-pipe question of repackaging academic (and by implication less relevant) knowledge. Again the gap looms large.

But although this unambiguously identifies a desire for specific, problem-solving knowledge, and bears similarities with the ethos of the engineering model of research, it also masks some more complex problems. For instance, where does the creativity and entrepreneurial skill desired by industry but apparently not produced through university education fit in? What about generating ideas to expand businesses in new and novel directions? How can potential problems be identified before they threaten competitive position?

NEW MODES OF KNOWLEDGE PRODUCTION

In response to this, some commentators argue that forms of knowledge production are themselves on the move. Starkey and Madan (2001) and Huff (2001) go along with Gibbons' (Gibbons *et al*. 1994) idea that recent years have seen the development of genuinely new forms of knowledge production. Looking (mostly) at the 'hard' sciences, these authors identify and trace the emergence of a new form of knowledge – Mode 2 – which departs from previous models of scientific knowledge – Mode 1 – in both structure and production. Mode 1 knowledge is discipline based: scientific method and theory development mattering more than practical implementation. In Mode 1 environments, the focus is on producing abstract and universal knowledge, not that which is specific, localized or concerned with practice. Mode 2 knowledge production is concerned with application and context;

> In Mode 1 problems are set out and solved in a context governed by the largely academic interests of a specific community. By contrast, Mode 2 knowledge is carried out in a context of application … In comparison with Mode 1, Mode 2 is more socially accountable and reflexive. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context (Gibbons *et al*. 1994: 3).

The problems associated with Mode 1 knowledge production, with its separation from non-academic domains and its fixed notions of what does and does not constitute valid knowledge, are important constituents of the relevance gap.

So does a shift towards Mode 2 forms of knowledge production change anything? Representations of Mode 2 imply that strong links can be forged between theory and application, and that knowledge can be generated through the intersection of academic and non-academic priorities. Mode 2 therefore stands as an example of highly relevant knowledge production. It is not just an accommodation of the need for relevance, but is actively constituted by it through an interconnected 'triple helix' of industry, academic institutions and government. Thus, in theory at least, following a Mode 2 'route' will lead to insightful, relevant and accessible research agendas with widely useful knowledge emerging from them.

A fully functioning Mode 2 environment brings together the networks and markets positioned as distinct throughout discussions of relevance gaps. It supposes a degree of institutional restructuring involving the creation of new measures of academic impact, increasing the speed of knowledge production and establishing cross-disciplinary, practice-oriented, time-relevant associations and journals. Because of this, popular characterizations of Mode 2 environments are perhaps more aspirational than real, after all, existing cross- and interdisciplinary journals currently struggle to find audiences and to achieve similar status to disciplinary-based journals. Regardless of whether there really is a move towards Mode 2 or not, the institutions and practices of academic business research still show many of the hallmarks of Mode 1 knowledge.

RELEVANCE AND RIGOUR REVISITED

On a more abstract level framing Mode 2 as a response to problems inherent in Mode 1 involves trading one overarching model of knowledge production for another. In other words a Mode 2 framing supposes a 'new form of knowledge production', not multiple new ways of analysing or developing the subtle co-constitution of academic and non-academic priorities. Discussions of Mode 2 also generally suppose that changing the focus of research activity towards the real world problems of the private sector is a positive step, and that this is (at least part of) the real business of researchers.

With reference to management research, Pettigrew (2001) argues that the debate over forms of relevant and rigorous knowledge production needs to be broadened out, to:

> use the Mode 1–Mode 2 dichotomy to open up debates about the character, quality and relevance of the knowledge we produce, and not slip into the easy but shallow option of saying that the answer lies in Mode 2 (whatever that is in practice) (Pettigrew 2001: 62).

In other words, the practice of doing relevant academic research cannot be reduced to the adoption of Mode 2 (seen here as a way of working). Pettigrew goes on to identify other necessary ingredients for relevance, in addition to those of scholarly quality. These he lists as:

- Engagement with the social science and management literatures; at appropriate moments and with appropriate partners, combining knowledge production and use.
- Ensuring the internal development of the fields of management while engaging with co-beneficiaries and co-producers.

- Challenging and transcending the current beliefs and knowledges of those stakeholders we work with while also engaging with those beliefs.
- Preserving researcher autonomy as a precondition to build scholarly identity and creativity, while encouraging different forms of engagement with stakeholder communities.

This is a useful list, if somewhat idealized. However, Pettigrew does recognize that reconciling academic and practitioner worlds is no easy task. Each of these requirements constitutes one of the 'double hurdles' for management research. These hurdles involve more than simply maintaining parallel streams of research or dissemination in academic and business fields. Instead, Pettigrew argues that the two domains are reflexively linked. The pursuit of knowledge driven by abstract, intellectual problems can have direct implications for practice, for instance in providing concepts and models (e.g. theories of the market), which practitioners use to frame and understand the contexts in which they operate. Also, moving too far away from academic lines of enquiry runs the risk of disconnecting research and research agendas from wider social scientific debates. This is a trend Pettigrew detects in the increasing fragmentation and specialization of management research and which is equally important for CM research which also takes concepts, theories and methodological approaches from elsewhere. Maintaining the rigour of CM research also involves positioning it alongside other related areas, such as management research or the social sciences.

CONCLUSIONS: RECONNECTING RELEVANCE AND RIGOUR

The aim of this paper was to highlight some of the issues involved in producing both relevant and rigorous research within construction management, and to show that this simple opposition of academic and industry worlds, approaches and epistemologies neither fully captures the complexities of the issue, nor provides any headway into resolving it. There are numerous related challenges and sets of inconsistent demands. Research funders want industry-engaged, problem-solving research on the one hand and publications in quality journals on the other. Industry seems to want easy, directly applicable solutions. Universities want quality dissemination of corpus knowledge through teaching and cutting edge research which both addresses industry problems (and has commercial application) and maintains academic reputation. These statements are, of course, themselves oversimplifications; firms do not necessarily know what they want, or understand fully the problems they face. Research funders select and change priorities and funding systems in attempts to resonate with industry and government. Universities undertake a wide range of research activities, pure and applied, practical and abstract.

In short, the debate over relevance and rigour is not straightforward. Simple dichotomization of the two, although prevalent in many discussions, masks the reflexive and recursive interactions between bodies of existing practitioner and academic knowledge, cutting edge research and emerging problems within the landscapes of both industry and academia. It also hides some important questions about the role of academic research in supporting industry and its positioning alongside other forms of enquiry.

One firm conclusion is that leaping these hurdles involves challenging as well as accommodating business expectations and requires a process of mutual realignment (not just academic accommodation), as well as recognition at the level of research funding that the call for increased relevance is not a simple one. Such an approach reaffirms the importance of producing academic insights which are relevant partly because they are not constrained by the immediate pressures of business. This is especially important considering that the priorities of firms are not always in harmony with wider society. The burgeoning field of corporate ethical and social responsibility is one such area where the continuous pursuit of increased competitiveness is criticized, especially in the context of environmentally unsustainable business practices.

Debates about the nature of useful knowledge typically point to significant discrepancies between business and academia. Conventions, expectations and interests are not necessarily commensurable. Although there is a perceived need to reconfigure existing modes of collaboration, wholesale transformations, for instance from Mode 1 to Mode 2 knowledge production, are neither universally desirable nor likely to occur. This is especially true given the intransigence of existing academic practices centred around peer review and practitioners' equally firm focus on immediate problems and the pursuit of conveniently packaged 'solutions'. This is also reflected in the large market for consultancy.

At the heart of the issue of relevance and rigour must lie the understanding that in practice, business and academia reflexively interact with and influence each other. Academic terminology enters business vocabulary and in turn frames the actions of practitioners, even if those actions transform 'original' meanings. For example, how often is the concept of 'culture' or of a 'culture clash' evinced by practitioners as a means of understanding conflict? This connection resonates particularly with construction management – an area which borrows conceptual tools and methods from elsewhere and requires a willing, if not actively collaborating industry as its laboratory. CM research cannot escape its connections to both academic and industrial arenas. It is through the explication and exploring of these that its relevance and rigour will be revealed.

REFERENCES

Bijker, W (1992) The social construction of fluorescent lighting, or how an artifact was invented in its diffusion stage. *In*: W Bijker and J Law (Eds.) *Shaping technology/building society studies in sociotechnical change*. Cambridge, MA: MIT Press.

Binks, M, Starkey, K *et al*. (2006) Entrepreneurship education and the business school. *Technology Analysis and Strategic Management*, **18**(1), 1–18.

Bourdieu, P (1986) *Distinction: a social critique of the judgement of taste*. London: Routledge & Kegan Paul.

Breslau, D (1997) Contract shop epistemology: credibility and problem construction in applied social science. *Social Studies of Science*, **27**, 363–94.

Bresnen, M and Marshall, N (2000) Partnering in construction: a critical review of issues, problems and dilemmas. *Construction Management and Economics*, **18**, 229–37.

Elzinga, A (1985) Research bureaucracy and the drift of epistemic criteria. *In*: B Wittrock and A Elzinga (Eds.) *The university research system: the public policies of the home of scientists.* Stockholm: Almqvist and Wiksell International.

Fernie, S, Leiringer, R and Thorpe, T (2006) Change in construction: a critical perspective. *Building Research & Information*, **34**(2), 91–103.

Gibbons, M, Limoges, C, Nowotny, H, Schwartzmann, S, Scott, P and Trow, M (1994) *The new production of knowledge: the dynamics of science and research in contemporary society*. London: Sage.

Green, S (1999) The missing arguments of lean construction. *Construction Management and Economics*, **17**(2), 133–7.

Harty, C and Shove, E (2004) Disciplines and their dynamics. Interactive Agenda Setting Discussion Paper, Lancaster University, available at www.lancs.ac.uk/fss/sociology/research/projects/iass/files/iass_workshop1_Shove_Harty_Disciplines_and_their_dynamics_PAPER.pdf.

HMSO (1993) *Realising our potential: a strategy for science, engineering and technology*, Cm.2250. London: HMSO.

Howells, J, Nedeva, M and Georghiou, L (1998) *Industry–academic links in the UK*. HEFCE.

Huff, A and Huff, J (2001) Re-focussing the business school agenda. *British Journal of Management*, **12**, 49–54.

Kaplan, A (1964) *The conduct of inquiry; methodology for behavioural science*. New York: Chandler Publishing Company.

Linder, J C and Smith, H J (1992) The complex case of management education. *Harvard Business Review*, 16–17 (Sept/Oct).

McCaffer, M (2007) Editorial. *Engineering, Construction and Architectural Management*, **14**(1) (forthcoming).

Pettigrew, A M (2001) Management research after modernism. *British Journal of Management*, **12**, 61–70.

Shove, E and Wouters, P (2005) Interactive agenda setting in the social sciences – interdisciplinarity. Interactive Agenda Setting Discussion Paper, Lancaster University, available at www.lancs.ac.uk/fss/sociology/research/projects/iass/files/iass_workshop3_Interdisciplinarity_Discussion_PAPER.pdf.

Starkey, P and Madan, P (2001) Bridging the relevance gap: aligning stakeholders in the future of management research. *British Journal of Management*, **12**, 3–26.

Whitley, R (1984) *The intellectual and social organization of the sciences.* Oxford: Clarendon Press.

HAVE THE ECONOMICS OF CONSTRUCTION GOT CLOSER TO BECOMING A RECOGNIZED SUB-DISCIPLINE OF ECONOMICS? CAN IT DO SO?

Graham Ive[1] and Chen-Yu Chang

Bartlett School of Construction and Project Management, University College London, Wates House, 22 Gordon Street, London, WCH1 0QB,UK

The degree of progress towards recognition of a field of academic activity as a sub-discipline can be measured by three kinds of flow: (1) systematic citation of theoretical work in the main discipline by authors writing in the literature of the putative sub-discipline; (2) some citation, in the literature of the main discipline, of sub-discipline studies applying main discipline theories to the practical field of specialization of the sub-discipline; and (3) some overlapping of authors, with some authors writing sometimes in the journals of the sub-discipline and sometimes in the main literature of the discipline or the parallel literatures of other, recognized, sub-disciplines. Papers published in *Construction Management and Economics* between 2000 and 2006 are examined. Papers meeting criterion (1) are classed as 'economics of construction', other papers as either construction management or 'building economics'. The papers classed as 'economics of construction' are analysed in terms of the *Journal of Economic Literature* classification system. Some findings are presented regarding the size of all three kinds of flow, and conclusions drawn.

Keywords: economic history, economic theory.

INTRODUCTION

In 1994, George Ofori distinguished between ‘construction industry economics’ (related to the application of economic theory to the study of the construction industry, its markets and firms) and ‘construction project economics’ (relating to cost planning, life cycle costing and value engineering) (Ofori 1994). Myers (2003) noted that the introductory cover of the journal *Construction Management and Economics* states that: “construction economics includes: design economics, cost planning, estimating and cost control, the economic functioning of firms within the construction sector, and the relationship of the sector to national and international economies.”

Ofori concluded that “construction economics cannot be described as a bona fide academic discipline. It lacks a clear indication of its main concerns and contents and a coherent theory. It is not recognized as a distinct part of general economics” (Ofori 1994: 304).

The purpose of this paper is to re-examine the history and condition of construction economics from the perspective of 2007 – in particular, whether the recent evidence still leads its reviewer to Ofori’s conclusion. If not, what are the signs of an emerging sub-discipline here? If so, what (if anything) can or should be done to change that?

[1] g.ive@ucl.ac.uk

THE INSTITUTIONAL SETTING FOR CONSTRUCTION ECONOMICS

Who might wish to achieve such an outcome of recognition, and why? For anyone wishing to specialize in the study of construction from within the institutional support system of economics (that is, university departments of economics, economics research council funding) it is an obvious necessity. However, as James Buchanan (1969) pointed out, not all practitioners of 'the economics of X' are in fact dependent on such support systems. Buchanan had in mind agricultural economics:

> "Within a single (economics) department, fields or areas of…specialization may be added, dropped, transformed…Agricultural economics is however different precisely because in most universities it is organised independently as a self contained departmental unit, often…in a wholly different school from that which houses…economics" (Buchanan 1969: 1028).

Building economics and engineering economics have shared this difference. Today, many emergent specialist 'economics of' s are likewise housed outside of economics departments – for example, in institutes of transport studies (transport economics) or of health studies (health economics), and may draw funding from engineering or medical research funding bodies. (For example, the website of the Institute for Transport Studies at the University of Leeds explains that its 'Economics and Behavioural Modelling Group' employs "some 17 transport economists working in the areas of: efficiency analysis, econometrics, competition economics, charging and pricing and project appraisal, … (its) research sponsored by Network Rail, Department for Transport, Office for Rail Regulation, the European Commission and UK research councils" (www.its.leeds.ac.uk/research/groups/ebmg-transeconomics.php).)

University departments of the built environment (bringing together some or all of the professional education of architects, surveyors, building engineers, builders, construction and project managers, undertaking research studies of built environment issues from either one of a range of disciplines or from an interdisciplinary perspective) mostly date back to the 1960s and 1970s in Britain, and certainly no further elsewhere.

'Building economics' as a way of earning a living is for practical purposes an outcome of the existence of such departments. 'Engineering economics' has a separate if partly parallel history within faculties of engineering and, more specifically for present purposes, within departments of civil and mechanical engineering.

In the USA, Stanford University's Construction Institute, within its Department of Civil Engineering, was formed in the 1960s. The ASCE divided its Proceedings into the journals of separate 'divisions', of which construction was one, in 1963.

ECONOMICS-AS-SOCIAL SCIENCE AND DECISION-ECONOMICS

Economics can be divided into a part that is social science, concerned with understanding and explaining human behaviour and institutions, and a part that is 'decision theory' – mathematics applied to permit more rational decision solutions to complex choice problems (Buchanan 1969).

On decision theory, to cite just one paper out of very many, Fishburn (1991) sees the history of microeconomics chiefly as a move from classical decision making under certainty to new theories of decision under risk and uncertainty. For Fishburn, and for the vast majority of economists, this work is ‘theoretical’ because it is concerned with the axiomatization of models of behaviour used, whilst experimental work on decision behaviour is pushing economists to redefine ‘rationality’ (for example, definitions in which utility is not necessarily either independent or transitive) (Tversky 1969; Tversky and Kahneman 1986; Machina 1982; Sonnenschein 1971).

But ‘decision economics’ pushes across the boundary of economics into management science. At the margin, the problem in deciding what is ‘economics’ and what is ‘management science’ is where to draw a line within the body of ‘management science’, between that part that is derived ultimately from economic theories of behaviour, use of mathematical and quantitative economic methods, and the drive towards formal modelling, and that part that has other sources.

We will therefore distinguish two kinds of economics, to which construction economics may or may not have a close relationship: ‘decision economics’ and ‘social-science economics’.

In construction economics, however, there is little evidence (with the partial exception of bidding strategies) that our mathematical decision techniques are actually in widespread use by the actors whose behaviour as economist / social scientist we are trying to understand, and therefore OR-type work has not (yet) in itself turned construction economics into a recognized sub-discipline of economics.

We propose to make the ‘decision economics of building’ as a term extend to cover not only classic OR applications to bidding strategy but also client multi-attribute choice problems, such as contractor and procurement route selection, and applications of options valuation techniques to real options within construction projects.

Were construction economics ever to generate by its own breakthrough work on, say, the valuation of real options, the kind of practical impact that finance theory has had on financial options then, like finance, it would no doubt find itself being assimilated and welcomed into the fold of economics,. We will explain why we think such a breakthrough-effect is unlikely in this case in the last section of this paper.

Until such time, the best that construction economics can aspire to, in terms of recognition, is that it may develop by applying propositions, taken from economics-as-social-science, to the understanding of behaviour and explanation of institutions within the world of construction.

CONDITIONS FOR THE ESTABLISHMENT OF A NEW SUB-DISCIPLINE

Insofar as economics is a vibrant source of ideas – some of which have the potential to illuminate the world of construction activity – and insofar as that world offers an interesting and distinctive field in which to apply and test some of those ideas, then presumably it would indeed be desirable in itself, though perhaps not without its opportunity cost, for there to be a recognized sub-discipline of economics. But, and here is the focus, how far is it from being achieved?

A sub-discipline of economics to exist and continue needs:

1. To achieve a dual recognition: *both* recognition of expertise of its specialists in either a limited field of human activity (an ‘industry’, as it might be, agriculture, transport, health care) or in a dimension or attribute of all activity (as it might be, an aspect of the spatial or the historical); *and* recognition of a distinctively ‘economic’ (discipline-based) approach to that subject matter – thus not ‘transport studies’ but the ‘economics of transport’, etc.; not urban studies but urban economics. (Frenzel and McCready 1979).
2. To meet a demand.
3. To attract resources and develop capacity.

It has been proposed that as an emergent sub-discipline reaches towards the stage of ‘professionalization’, it will show most of the following (Davis 2002):

1. Specialty journals.
2. Organization of associations and societies.
3. Regular scholarly association meetings both apart from and in conjunction with general economics meetings.
4. Inclusion of the field in scholarly classification systems (e.g. the *Journal of Economic Literature, Social Science Citation Index*).
5. University instruction and doctoral supervision dedicated expressly to the field.
6. Ability of individual academics to credential themselves for careers within universities by work done in the field.
7. Book publishing opportunities with major publishers for scholars in the field.
8. Identification of special library collections.
9. Newsletters, bulletins, electronic lists.

It is proposed in the present paper that a necessary but not sufficient condition for a body of academic activity to be a recognized sub-discipline of a wider discipline is that there be two-way traffic between them. The sub-discipline, if it is to be such, will draw theoretical and methodological ideas from the wider discipline, and some results from work in the sub-discipline will receive attention from some practitioners of the main discipline or of other parallel sub-disciplines.

This paper is limited to examining the flows of theory and its application, and in one direction only, and neglects matters of methodology, as suitable subject for a separate study.

If indeed there are flows of the kind described above then, as a minimum, it follows that at the least there will be:

1. A process of systematic citation of theoretical work in the main discipline by authors writing in the putative sub-discipline.
2. Some reverse citation, most especially of the findings of studies applying main discipline theories to the practical field of activity that is the special interest of practitioners of the sub-discipline (sub-disciplines are often, in the social sciences, the nearest thing the pure theorists have to laboratories). Ideally, though this is more than a minimum requirement, some identification by the sub-discipline of phenomena paradoxical in terms of received theory.

3. Some overlapping of authors, so that some authors write sometimes within the journals and literature of the sub-discipline, and at other times within the 'main' literature of the parent discipline or the 'parallel' literatures of other sub-disciplines. This paper examines flow 1.

There are of course other conditions that must be met and other tests for the healthy existence of a sub-discipline. However, it seems to us plausible to propose that if these conditions of authorial relationship and cross-citation are not met, then the other conditions (such as: ability of the sub-discipline to attract young researchers trained in the parent discipline) are unlikely to be met.

We will therefore begin by imposing a distinction upon the kinds of work found in the literature of the putative sub-discipline: between works that do systematically cite theoretical work in economics, and those that do not.

In the empirical part of the paper, we will use the term 'building economics' (short for: 'building and engineering economics') for papers that: refer only or mainly to built environment literature, including other works of building economics or economics of construction, and not directly to economics literature. The influence of economic theory upon such work is not therefore necessarily absent, but it is at most indirect, mediated through the other works that are cited.

We will use the term 'economics of construction' for papers in construction management journals (specifically, CME) that, regardless of the manner of use or the outcomes achieved, do at least explicitly cite works of economic literature (either decision-economics or economics-as-social-science) as sources for their theoretical ideas and propositions.

Finally, we will use the term 'construction economics' as the overarching inclusive term for both 'building economics' and 'economics of construction'.

This distinction is not meant to be invidious, or to imply superiority in general of one kind of paper over the other. On the contrary, one can easily imagine several reasons why the achievements and qualities of the body of 'building economics' literature might be judged superior to those of its 'economics of construction' counterpart – certainly if judged from perspectives other than those of a theoretical economist. Nevertheless, to that economist, the literature of 'building economics' is unlikely to seem to be 'economics' at all – rather to be a field, perhaps like the academic study of accountancy, in which there is some overlapping with economics of language and concerns (For example, Bajari and Tadelis (2001), discussing the literature of procurement contracts in the RAND *Journal of Economics*, divide this sharply into the economic theory literature, exemplified by Laffont and Tirole (1993) and McAfee and McMillan (1988) and "by contract, the descriptive engineering and construction management literature" (in this category citing, *inter alia*, Ashley and Workman 1986; Finkel 1997; Hester *et al*. 1991; and Ibbs *et al*. 1986)).

A BRIEF HISTORY OF CONSTRUCTION ECONOMICS

The argument of this section is that the boundaries of construction economics have been set largely by changes in its institutional relationships to housing and property economics; and that, within those boundaries, developments of the agenda of construction economics have unevenly taken up opportunities opened by earlier developments in economics itself.

Stage 1 – up to the 1970s - no journal, no specialists

Before economic specialists in built environment departments existed, occasional economists made forays out from economics departments into the world of construction. Of these, Marion Bowley on innovation (1966) has perhaps had the most influence upon ‘construction economics’ in the UK, and Mills (1972) on labour and industrial relations in the US. Studies were mostly macroeconomic (see below) and work on costs and price formation (Andrews and Brunner 1975; Cassimatis 1969) stands out as exceptions.

Intellectually, in microeconomics the years from the 1930s to the1970s were the period between the fall of the ‘old institutionalism’ in economics and the rise of the new (Hodgson 1993). It has been argued by Hodgson that it was indeed the case that microeconomic theory then offered rather little to the would-be student of a particular industry and its firms, and that neoclassical economics was hostile to the very concept of an industry. (*The Journal of Industrial Economics* was founded and edited in the 1950s largely by economists sympathetic to the heterodox and, in orthodox neoclassical circles, hostilely received work of the ‘Oxford group’, such as PWS Andrews.) Nevertheless, to take two examples of influential early works of construction economics, the lack of reference to microeconomic theory in either Bowley (1966) or Turin (1975) is, in retrospect, striking. On the other hand, those early micro-economists of construction that did acknowledge theoretical debts tended towards the heterodox, taking their inspiration not from orthodox neo-classical microeconomics but from sources such as Shackle (Hillebrandt 1974).

Meanwhile, the 1950s were the key decade for the establishment of Operations Research (hereafter, OR) (the eponymous journal began in 1953, *Operational Research Quarterly* and the *Journal of the Operational Research Society* both in 1950). This marked the emergence of ‘decision theory and application’ as an important offshoot of economics. An early application to construction (bidding strategy) was by Friedman (1956).

Economics-of-construction studies of building cycles and the determinants of long term fluctuations in construction demand in advanced industrial economies (JEL E3) first flourished, largely as a series of monographs (Lewis 1965; Richardson and Aldcroft 1968; Burns 1935; Long 1940; Isard 1942a, 1942b; Kuznets 1930, 1958; Abramovitz 1961, 1968), then fell with the emergence of the view that such long building cycles (Kuznets cycles) and their drivers had become things of the past, suitable only for study by economic historians (Abramovitz 1968).

Another important early offshoot, not surprisingly given the then-salience of ‘development studies’ and ‘development economics’ (JEL O), was work on ‘the construction sector in economic development’. Of work published in economics journals, the paper most influential on the economics of construction was by Strassmann (1970), and the book with most influence that by Hirschman (1958). Hirschmanian linkages were taken up by Jones (1976) and Schultz (1976) – the latter published in Polenske and Skolka (eds.), a work on ‘Advances in Input-Output Analysis’, a topic soon to be the subject of a series of papers by Bon in economic journals (1977, 1984, 1986) (JEL O18, O41, D57, R15). This body of work was the product mainly of economists who were not (or not yet) located in built environment departments and who were economists rather than construction economists. Interest in these topics however fell with the fall in ‘development economics’ (Lal 1985; Krueger

1990) and in economic planning around fixed (Keynesian/neo-Ricardian) production technology proportions.

Stage 2 – from 1982-3 to the present – journals, and specialists

CME of course was founded in 1982, and the *Journal of the Construction Division of ASCE* was replaced by the *Journal of Construction Engineering and Management* in 1983. These events helped to separate construction economics from urban, property and housing economics, and to facilitate the decision-economics of construction by conjoining construction economics with construction management.

By the late 1970s, both regional and urban economics (JEL R) were booming, within which housing economics was emerging as a sub-discipline (R21 Housing Demand, and R31 Housing Supply and Markets). Housing economics was soon to occupy a large part of journals about space and products fixed in space, such as *Urban Studies, Housing Studies, Environment and Planning.* Departments of Land Economy, Real Estate, Planning and Urban Policy all grew, and often housed researchers working on housing and commercial property supply (and thus its development industries) as well as demand. It is in the late 1970s and early 1980s that 'real estate economics' and 'housing economics' become detached from 'construction economics' in the UK. The practical disadvantages of this split for the latter included loss of funding streams and rich markets for research and teaching. The intellectual disadvantages of the separation included an excessive separation of the economics of construction from the broader economics of the development process, including issues of land, user demand and financial assets (Bon 1989, 2001; Ive 2005). The compensating intellectual advantage was the resulting focus upon relationships between construction clients and their contractors.

This brings us then to the economics of the industrial organization (JEL L) of construction. In the 1970s, the 'old industrial economics' paradigm of structure-conduct-performance prevailed (Bain 1956, 1968). Within it, construction in advanced industrial economies was most obviously characterized by its low levels of national market concentration, and by being 'closed' to international competition.

The economics of organization was then transformed within a decade. Alchian and Demsetz's generally influential paper on the consequences of information costs came in 1972 and Williamson's book on the make-or-buy market or hierarchy paradigm in 1975. Soon came Klein *et al*. (1978) and Dahlman (1979). Eccles' two papers – much cited in the literature of the economics of construction – appeared in 1981 but the emerging transaction cost economics and economics of information was not taken up for construction until Reve and Levitt (1984), Stinchcombe (1985) and Winch (1989). It is notable that Eccles, Stinchcombe and Winch are all sociologists and not economists by original discipline, and became students of organizations from that route.

From the 1980s, onward fields began to emerge and gain recognition within economics that potentially bear closely upon the practical concerns of construction economics. These include: transactional relationships, contracts and reputation, networks (JEL L14), contracting-out and joint ventures (L24 and L33).

Meanwhile, the economics of auctions (JEL D44) received a stimulus. It is instructive to compare two early surveys by Engelbrecht-Wiggans (1980) and McAfee and McMillan (1987). The former appeared in *Management Science*, reviewed a bidding strategy (bidder decision) literature (some game-theoretic in method, some not) that had mostly (though by no means entirely) been published in OR or management science journals. The latter was able to report a new wave of interest by theoretical economists, and to answer the question “why study auctions?’ as follows (1987: 699-700):

> Some of the most exciting of the recent developments in microeconomic theory have been in the modelling of strategic behaviour under asymmetric information.

This is indeed economics-as-social-science, with a remit much broader than bid decision-support.

Important works of economics applied to construction written by non-specialist economists around 15–20 years ago include: Laffont and Tirole (1993), McAfee and McMillan (1986, 1988), and Dasgupta and Spulber (1989) on procurement auctions; Masten *et al*. (1991) and Lee and Png (1990) on temporal specificity; De Long and Summers (1991 and 1993) on investment and economic growth.

The ‘Findings’ section below will show the evidence (or lack of it) for the impact of these developments in economic theory upon the ‘economics of construction’ literature.

METHOD OF DATA COLLECTION AND ANALYSIS

The empirical scope of this study is confined to papers published in *CME,* between 2000 and 2006. This was by far the most prominent journal, in that period, to contain the words ‘construction’ or ‘building’ and the word ‘economics’ in its title. It therefore seems likely that here, if anywhere, is the first place to begin looking for evidence of a sub-discipline, on the criteria outlined in Section 4.

We reviewed the titles and keywords of all papers published in CME for signs or indications that the paper in question *might* be a work of the economics of construction, in the above sense, and *might* make reference to the literature of economic theory or to other recognized sub-disciplines of economics (excluding those of mathematical and quantitative methods, JEL C).

We took a ‘recognized sub-discipline of economics’ to mean one listed in the *Journal of Economic Literature* (JEL) classification system, D to R.

We then examined the references at the end of each ‘candidate’ paper, as follows. First, works not in English and all dissertations were removed because of practical difficulties in accurately classifying their discipline; as were (in part to minimize self-citation by authors, and in part because of difficulty of classification as economics) working papers and research reports except for those of a small number of institutions where we were confident that the discipline would be economics: for example, the World Bank, Bank of International Settlements, National Bureau of Economic Research. We removed references to basic (undergraduate) economics textbooks. We removed non-theory references to data sources, e.g. to yearbooks of statistics. We then removed all references published in building/construction journals, or books having construction or building in their title, unless their author was known also to publish in the recognized economic literature. The remaining journal papers and books were then each allocated to just one JEL class (sometimes with a cross-reference to other classes). Cited works were classed as ‘economics’ if either the journal in which they were published was one usually treated in libraries as an economics journal *or* if the title of the paper or book contained the word ‘economics’ (or a derivative thereof) or the words ‘theory’ or ‘model’ followed by a recognizable reference to an area of economic theory.

References to papers in OR or decision economics journals were distinguished from references to other economics.

At the junctions of construction economics with its ‘neighbours’ within economics, we have assumed those neighbours are themselves recognized sub-disciplines of economics – as for example with housing and property economics.

We next discarded purely methodological references (for the reasons explained above), for example to works on econometric techniques or time series modelling or statistics.

When in doubt we tried to err on the side of breadth in deciding what would count as a reference to a work of economics. For example, we treated Michael Porter’s many books as instances of application of the ideas of industrial economics rather than solely as works of management. We thus formed a ‘grey’ category of works cited that were neither unambiguously ‘in’ nor ‘out’ of the literature of economics.

If this left a minimum of five works unambiguously ‘in’, or eight or more that were either ‘in’ or ‘grey’, we considered the paper that had cited these works as being within the sub-set of *CME* papers qualifying for discussion here.

Evidently, there is an element of subjectivity in the procedures described above. If another pair of construction economists was to attempt to replicate the process of identification they might, at the margin, not exactly replicate our results. However, we are confident that such replication would not identify significant numbers of *CME* papers of ‘economics of construction’ that we missed, unless the researchers were to take issue with our boundaries between ‘theory’, ‘method’ and ‘OR’ literatures.

FINDINGS: THE BRANCHES OF ECONOMIC THEORY REPRESENTED IN *CME*

It is not clear whether or not there is a trend towards more ‘economics of construction’ in *CME*. On a generous definition (5+ refs to economic literature, as defined above), we count:

- 2006 = 15 papers (affected by special issue for Ranko Bon, to some extent).
- 2005 = 7 papers.
- 2004 = 15 papers.
- 2003 = 8 papers.
- 2002 = 12 papers.
- 2001 = 12 papers.
- 2000 = 4 papers.

Table 1: ‘Economics of construction’ papers in CME, 2000–2006

Economics of:	**2006**	**05**	**04**	**03**	**02**	**01**	**00**	**total**
Excluded (example):								
Price indices: time series modelling, regression, forecasting (tender price indices) (refs. to methods and works of building economics)			*1*		*1*	*1*	*1*	*4*

Included:								
Microeconomics (D)								
Transaction cost and property rights economics: total D23 (Organizational behaviour; transaction costs; property rights)	2		1		1	3	2	9
Transaction cost economics: [A] Boundaries of firm, make or buy, subcontracting	*2*		*1*			*1*	*1*	*5*
Transaction cost economics: [B] Transaction governance: inc. relational contracting *Could class also at L14 (Transactional relationships; contracts and reputation; networks)*					*1*	*2*		*3*
Property rights: [C]							*1*	*1*
Total Factor Productivity: production frontier functions; inefficiency; indirect measurement of TFP D24 (Production, cost, capital productivity, total factor productivity, capacity)	1		1	1				3
Market structure and pricing D4	1							1
Bidding (refs. mainly to operational research literature) D44 Auctions		1	1		2			4
Input-output analysis D57 (Input-output tables and analysis)	2	1		1				4
Macroeconomics (E)								
Building (and property) cycles and demand forecasting, and price expectations E3 (Prices, business fluctuations and cycles)		2			1	2		5
Capital stock, gross and net capital formation, depreciation, lifespan of capital, obsolescence E22 (Capital, investment, capacity)			1					1
E26 Informal economy; underground economy	1							1
International economics (F)								
Multinational firms in construction / international construction F23 (Multinational firms; international business)		1	1	2				4
Financial economics (G)								
Agency (incentive and information) problems: and application to corporate governance G3 (Corporate finance and governance)	1							1
Uncertainty and value of real options: total G13 (Contingent pricing; futures pricing) [also relates to D8 (Information, knowledge and uncertainty) and specifically to D81 (Criteria for decision making under risk and uncertainty)]	4		3		3	1		11
Uncertainty and value of real options: [A] to client / developer / owner, inc. BOT projects	*3*		*2*		*3*			*8*
Uncertainty and value of real options: [B] to contractor, inc. production resource allocation under uncertainty; pricing bids under resource cost uncertainty, with real options to switch technique and reschedule work	*1*		*1*			*1*		*3*
Labour economics (J)								
Labour productivity (LP): inc. direct measurement of output and labour input indices J24 (Human capital; skills; occupational choice; labour productivity)					1			1
J3 (Wages and labour costs); J31(Wage level and structure; wage differentials)			1					1
J4 (Particular labour markets); J41 (Labour contracts)			2					2
J6 (Mobility; unemployment; vacancies); J61 (Geographic labour mobility, migrant workers)						1		1

Industrial organization (L)								
‘Old’ industrial economics: Market structure, Competition, Concentration			1		1	2	1	5
L1 (Market structure, firm strategy and market performance)								
L14 Transactional relationships; contracts and reputations; networks (see D23 TCE where these are actually counted)					*1*	*2*		*3*
Firms – evolution, growth, economies of scale and scope, competencies	1		1	1	1			4
L2 (Firm objectives, organization, behaviour); L25 (Firm performance: size, diversification, scope)								
Regulation – pricing of natural monopolies (BOT)				1				1
L51 (Economics of regulation)								
Economic development, technological change and growth (0)								
Economic development, economic growth		1	1	1	1	2		6
O1 (Economic development)								
Innovation	2	1	1	1	1		1	7
O3 (Technological change; research and development; innovation)								
Environmental and ecological economics (Q)								
Environment						1		1
Q4 (Energy); Q5 (Environmental economics)								
Total by sub-heading								
D Microeconomics								*21*
E Macroeconomics								*7*
F International economics								*4*
G Financial economics								*12*
J Labour economics								*5*
L Industrial organization								*10*
O Economic development, technological change and growth								*13*
Q Environmental and ecological economics								*1*
Total by year (over 7 years)	15	7	15	8	12	12	4	73
Average of just under 10 papers per year								
10 JEL 2-digit (e.g. D2) ‘topics’ with 4 or more papers each								63
5 JEL 3-diit (e.g. D23) ‘topics’ with 4 or more papers each (viz. D23; D44; D57; F23; G13)								31

Text not in parentheses is our description of the content of the papers allocated by us to that row.
Terms in parentheses are the names of JEL classes or sub-classes.
Text and numbers in italic are sub-sets of totals shown in other rows in bold.

Some 63 of the 73 papers fall into 10, admittedly sometimes broad, 2-digit JEL classes (JEL D to R contains 103 2-digit classes).

Table 1 and Appendix A show that of these 10 classes (63 papers), 7 (36 papers) represent pre-established fields within the earlier economics of construction that would be found in a similar analysis of the contents of *CME* in its first decade (bidding strategy; input-output; building cycles; multinational firms; market structure; firm performance, size and scope; economic development). (Mainly) new fields are: organizational behaviour/transaction costs/property rights; futures pricing/decision making under risk and uncertainty; and innovation (27 papers).

Areas of economic theory potentially relevant to construction economics and transformed in recent decades but not significantly reflected in the pages of *CME* include: applications of agency theory to incentive and information problems (only

Chang *et al*.2006); public choice theory; contract theory; intertemporal firm choice; information and market efficiency; corporate financing policy; procurement theory; compensation packages / payment methods; information and product quality; environmental and ecological economics.

Decision economics in *CME*

Most papers on bidding published in *CME* draw on other papers in construction economics and OR literatures, not on modern economic theory of auctions or procurement. The construction economics and OR literatures on bidding are particularly close, with the same authors often contributing to both.

The new literature on valuing real options is also a form of 'decision economics' and intersects with the OR literature (certainly real options papers sometimes cite papers in OR journals).

If we were to take bidding strategy and real options valuation together, and call them both 'decision economics', then together these would account for by far the greatest single slice of economics-based papers published in *CME* (4 + 11 = 15 papers), but a relatively small total compared to all 'economics-as-social-science' papers.

Gates (1967), Park (1966) and Friedman (1956) are much-cited classics of the CME bidding literature. The classic paper by Black and Scholes (1973) is cited in almost every CME real options paper. Books by Trigeorgis (1995; Brennan and Trigeorgis, 2000) are also much cited on real options.

Economics-as-social-science in *CME*

Occasionally, economics-based papers appear in *CME*, which seem at present refugees from their natural homes elsewhere. Examples would be Wong *et al*. (2005) and Hsieh (2005), both of which would belong in a journal of property / real estate or housing economics; and Johnstone (2004), which would belong in a journal such as *Environment and Planning* or *Housing Economics*. Duncan, Philips and Prus (2006) is in *CME*, it would seem, because the application is to building projects, though other papers by the authors are in journals of labour economics – their key concern is with wage regulation and its effects. A future increase in the number of such papers would have interesting implications for recognition of the journal within economics.

The most-cited 'economics' authors in *CME* 'economics of construction' papers include: Porter, Dunning (neither of whom publishes much in purely 'economics' journals), Casson, Williamson, Coase, Foss, Nelson and Winter. There does seem to be a substantial time lag before mainstream journal papers start to be regularly cited in CME.

In addition to our analysis of the contents of *CME*, we looked for signs of 'reporting back' to the broader economics community, in papers by construction economists in mainstream journals. Only a very small number of authors published both in CME and in recognized economic journals, in the period 2000–6.

Construction management and construction economics in CME

By analysis of their references, papers in *CME* in principle can be broken down into: 'management of construction' (by analogy with 'economics of construction', papers drawing on management theory or other management sub-disciplines), 'building management' (by analogy with 'building economics', drawing on other construction-specific management literature), ‘economics of construction’, and ‘building economics’.

However, whilst a proportion of *CME* papers draw overwhelmingly on just one of these four source areas, most draw upon two or more. This diversity and indeed inter-disciplinarity (across management science and economics disciplines) is characteristic of the journal, and is perhaps its greatest strength.

Building economics in *CME*

There are topics where building economics has developed a substantial body of cross- (self-) referencing literature, within *CME* and outside of it: for example, tender price indices (forecasting), or the evidence for and implications of ‘Bon curves’.

Most common publications for references cited in ‘building economics’ papers were ASCE journals, CIB proceedings, *CME* itself, BRI, ECAM, IJPM, ARCOM proceedings, Habitat International.

CONCLUSION

We found *CME* to contain little ‘pure economics of construction’, that is, papers with theory references solely to economics literature, but to contain more papers at the interface between economics and management, as measured by roughly equal citation of each type of source of ideas (e.g. boundary of the firm literature).

It seems therefore that we can conclude that the economics of construction is still closer to ‘management of construction’ than will be most economics papers to any body of management literature and that ideas coming out of economics do not predominate in it relative to those coming out of management science.

We also found a substantial body of papers that we categorized as ‘building economics’, because of their lack of reference to recognized economics.

Partly at issue in the assessment of ‘building economics’ relative to the ‘economics of construction’ is the extent of ‘uniqueness’ of construction. Certainly, it is specific. But there are two views – in one, it is so specific that it can hope to take little from a general literature developed with any and all industries or economic activities in view; its community of students must therefore learn collectively to be self-reliant. On the other view, if economics operates at too high a level of generality to be applicable, that is either the fault of mainstream economists developing ‘the wrong kind of economics’, or the fault of construction economists for failing in their task of adaptation.

The economics of construction should ‘ideally’ face two ways: back towards the sources of its ideas (which should include the economics profession), to whom it can report on applications of theory, and forward towards the users of its normative work, to whom it can make recommendations. Meanwhile it also needs to look ‘sideways’ at itself, developing positive analysis whose value lies in adding to our understanding of why construction is organized as it is – something of critical importance for the development of CE, but which is not perhaps a main concern either to mainstream economists or to construction ‘users’.

Since our analysis utilized publications in *CME*, it is perhaps apposite to conclude with some reflections on the impact of the existence of that journal on construction economics. There are aspects of quantity as well as quality to the matter of attracting attention. If the works we have labelled as ‘economics of construction’ that have appeared in *CME* (together with those in other construction management journals) were to appear on their own, not hidden in a broader body of diverse work, they might just be enough to sustain a slim quarterly journal. This journal would then be more visible as a place to look for papers on: the boundary of the firm in a project-based industry characterized by much subcontracting, on governance structures for long-lived and uncertain transactions, on I-O analysis for capital goods industries, on real options in investment projects, on international corporations in fields where literal exportation of products is not feasible, etc (i.e. topics broader than construction, but for which construction provides an important instance and source of evidence). But what would then be lost is that the built environment professional community, and the broader building research community might pay this work less attention than it currently gets by appearing in 'broad' journals like *CME*.

It is also doubtful that the set of topics listed in the previous paragraph have enough coherence as a set to sustain a separate journal. One has only to imagine what that journal might be called? The 'Journal of economics of projects and project-based industries' might satisfy some contributors, but not all – and would encounter resistance for encroachment on the preserves of others.

Usefulness is often, though not invariably, the precursor of recognition for a sub-discipline. Construction economics' relationships to a body of non-academic users will not be revealed by analysis of references. However, the challenges listed in Lander and Pinches (1998) to the practical implementation of real option models and valuation methods would seem to apply *a fortiori* to the decision economics of building. The assumptions we require for modelling are all too often violated in practical application, and our models neither well known to, nor understood by, the relevant body of practitioners. The small size and relatively unsophisticated nature of most construction firms, the heterogeneity of the decisions, and the occasional nature of most construction clients, combine to form an inauspicious 'demand side'.

Finally, the 'national' salience of the economics of construction would seem to be not unrelated to the share and role of construction in an economy. It is surely no co-incidence that the authorship profile of economic papers in *CME* now contains so many Chinese names. The combination of UK-influenced academic and professional institutions with East Asian shares of construction in GDP appears to offer particularly favourable circumstances (Hong Kong, Singapore, Malaysia).

REFERENCES

Abramovitz, M (1961) The nature and significance of Kuznets cycles. *Economic Development and Cultural Change*, 9(3), 225–49.

Abramovitz, M (1968) The passing of the Kuznets cycle. *Economica*, **35**(140), 349–67.

Alchian, A A and Demsetz, H (1972) Production, information costs, and economic organization. *American Economic Review*, **62**(Dec), 777–95.

Andrews, P W S and Brunner, E (1975) *Studies in pricing*. London: Macmillan.

Ashley, D and Workman, A (1986) *Incentives in construction contracts*. Construction Industry Institute, Document SD-8, Austin, TX.

Bain, J S (1956) *Barriers to new competition*. Cambridge (MA): Harvard UP.

Bain, J S (1968) *Industrial Organization*. New York: Wiley.

Bajari, P and Tadelis, S (2001) Incentives versus transaction costs: a theory of procurement contracts. *RAND Journal of Economics*, **32**(3), 387–407.

Black, F and Scholes, M (1973) The pricing of options and corporate liabilities. *Journal of Political Economy*, **81**, 637–59.

Bon, R (1977) Some conditions of macroeconomic stability of multiregional input-output models, *Economic Analysis*, 16 (1), 65-87.

Bon, R (1984) Comparative stability analysis of multi-regional input-output models: column, row and Leontief-Strout gravity coefficient models. *Quarterly Journal of Economics*, 99 (4), 791–815.

Bon, R (1986) Comparative stability analysis of demand-side and supply-side input-output models: the case of the US. *International Journal of Forecasting*, **2**(2), 231–5.

Bon, R (1989) *Building as an economic process*. Englewood Cliffs (NJ): Prentice Hall.

Bon, R (2001) The future of building economics: a note. *Construction Management and Economics*, **19**, 255–8.

Bowley, M (1966) *The British building industry: four studies in response and resistance to change*. Cambridge: Cambridge University Press.

Brennan, M and Trigeorgis, L (2000) *Project flexibility, agency and competition: new developments in the theory and application of real options*. Oxford: Oxford University Press.

Buchanan, J M (1969) A future for agricultural economics? *American Journal of Agricultural Economics*, **51**(5), 1027–36.

Burns, A F (1935) Long cycles in residential construction. *In: Economic essays in honour of Wesley C. Mitchell*. New York.

Cassimatis, P J (1969) *Economics of the construction industry*. New York: National Industrial Conference Board.

Chang, C-Y, Chou, H-Y and Wang, M-T (2006) Characterizing the corporate governance of UK listed construction companies. *Construction Management and Economics*, **24**(6), 647–56.

Dahlman, C J (1979) The problem of externality. *Journal of Law and Economics*, **22**(1), 141–62.

Dasgupta, S and Spulber, D (1989) Managing procurement auctions. *Information Economics and Policy*, **4**(1), 5–29.

Davis, J B (2002) The history of economics as a subdiscipline: the role of the History of Economics Society meetings. *History of Political Economy, Annual Supplement*, **34**, 62–76.

De Long, J B and Summers, L (1991) Equipment investment and economic growth. *Quarterly Journal of Economics*, **106**, 445–502.

De Long, J B and Summers, L (1993) How strongly do developing countries benefit from equipment investment? *Journal of Monetary Economics*.

Duncan, K, Philips, P and Prus, M (2006) Prevailing wage legislation and public school construction efficiency. *Construction Management and Economics,* **24**(6), 625–34.

Eccles, R G (1981) Bureaucratic versus craft administration: the relationship of market structure to the construction firm. *Administrative Science Quarterly*, **26**(3), 449–69.

Eccles, R G (1981) The quasifirm in the construction industry. *Journal of Economic Behavior and Organization*, **2**(4), 335–57.

Engelbrecht-Wiggans, R (1980) Auctions and bidding models: a survey. *Management Science*, **26**(2), 119–42.

Finkel, G (1997) *The economics of the construction industry*. New York: Sharpe.

Fishburn, P (1991) Decision theory: the next 100 years. *Economic Journal*, **101**(404), 27–32.

Frenzel, K A and McCready, D J (1979) Health economics: a subdiscipline? *Economic Development and Cultural Change*, **27**(2), 267–82.

Friedman, L (1956) A competitive bidding strategy. *Operations Research*, **4**, 104–12.

Gates, M (1967) Bidding strategies and probabilities. *Journal of the Construction Division, ASCE*, **93**, 75–107.

Hester, W, Kuprenas, J and Chang, T (1991) *Construction changes and change orders: their magnitude and impact*. Document SD-66, Construction Industry Institute, Austin, TX.

Hillebrandt, P M (1974) *Economic theory and the construction industry*. London: Macmillan.

Hirschman, A (1958) *Strategy of economic development*. New Haven: Yale University Press.

Hodgson, G (1993) Institutional economics: surveying the 'old' and the 'new'. *Metroeconomica,* **44**(1), 1–28.

Hsieh, HHY (2005) The 1990s Taiwan residential construction boom: a supply side interpretation. *Construction Management and Economics*, **23**(3), 265–84.

Ibbs, C W *et al*. (1986) *Determining the impact of various construction contract types and clauses on project performance: volumes I and II,* Documents SD-10 and 11, Construction Industry Institute, Austin, TX.

Isard, W (1942a) A neglected cycle: the transport building cycle. *Review of Economics and Statistics*, **24**(4), 149–58.

Isard, W (1942b) Transport development and building cycles. *Quarterly Journal of Economics*, **57**, 90–112.

Ive, G (2005) Review of Evans, A (2004) Economics, real estate and the supply of land. *Construction Management and Economics,* **23**, 767–773.

Johnstone, I M (2004) Development of a model to estimate the benefit-cost ratio performance of housing. *Construction Management and Economics*, **22**(6), 607–17.

Jones, L P (1976) The measurement of Hirschmanian linkages. *Quarterly Journal of Economics*, **90**(2), 323–33.

Klein, B, Crawford, R A, and Alchian, A (1978) Vertical integration, appropriable rents, and the competitive contracting process. *Journal of Law and Economics,* **21**, 297–326.

Krueger, A (1990) Government failures in development. *Journal of Economic Perspectives*, **4**(3), 9–23.

Kuznets, S (1930) *Secular movements in production and prices*. New York: Houghton Mifflin.

Kuznets, S (1958) Long swings in the growth of population and related economic variables. *Proceedings of American Philosophical Society*, **102**(1), 25–52.

Laffont, J. and Tirole, J. (1993) *A theory of incentives in procurement and regulation.* Cambridge, MA: MIT Press.

Lal, D (1985) The misconceptions of development economics. *Finance and Development*, **22**(2), 10–13.

Lander, D M and Pinches, G E (1998) Challenges to the practical implementation of modelling and valuing real options. *Quarterly Review of Economics and Finance*, **38**, 537–67.

Lee, T K and Png, I P L (1990) The role of instalment payments in contracts for services. *RAND Journal of Economics*, **21**(1), 83–99.

Lewis, J P (1965) *Building Cycles and Britain's Growth*. London: Macmillan.

Long, C D (1940) *Building cycles and the theory of investment*. Princeton, NJ: Princeton University Press.

Machina, M (1982) Expected utility analysis without the independence axiom. *Econometrica*, **50**(March), 277–323.

Masten, S E, Meehan, J W and Snyder, E A (1991) The costs of organization. *Journal of Law, Economics and Organization*, **7**(1), 1–25.

McAfee, R P and McMillan, J (1986) Bidding for contracts: a principal-agent analysis. *RAND Journal of Economics*, **17**(3), 326–38.

McAfee, R P and McMillan, J (1987) Auctions and bidding. *Journal of Economic Literature*, **XXV**, 699–738.

McAfee, R P and McMillan, J (1988*) Incentives in government contracting*. Toronto: University of Toronto Press.

Mills, D Q (1972) *Industrial relations and manpower in construction*. Cambridge, MA: MIT Press.

Myers, D (2003) The future of construction economics as an academic discipline. *Construction Management and Economics*, **21**(2), 103–6.

Ofori, G. (1994) Establishing construction economics as an academic discipline. *Construction Management and Economics*, 12, 295–306.

Park, W R (1966) *The strategy of contracting for profit*. Englewood Cliffs, NJ: Prentice Hall.

Polenske, K R and Skolka, J V (eds.) (1976) *Advances in input-output analysis*. Cambridge, MA: Ballinger.

Reve, T and Levitt, R E (1984) Organization and governance in construction. *International Journal of Project Management*, **2**(1), 17–25.

Richardson, H. W. and Aldcroft, D. H. (1968) *Building in the British economy between the Wars.* London: Allen and Unwin.

Schultz, S (1976) Intersectoral comparisons as an approach to the identification of key sectors. *In:* K R Polenske and J V Skolka (Eds.) (1976) *Advances in input-output analysis.* Cambridge, MA: Ballinger.

Sonnenschein, H (1971) Demand theory without transitive preferences, with applications to the theory of competitive equilibrium. *In*: J S Chapman *et al*. (Eds.) *Preferences, utility and demand*. New York: Harcourt Brace.

Stinchcombe, A (1985) *Organization theory and project management*. Oxford: Oxford University Press.

Strassmann, W P (1970) The construction sector in economic development. *Scottish Journal of Political Economy*, **17**(3), 391–409.

Trigeorgis, L (Ed.) (1995) *Real options in capital investments: models, strategies and applications*. Westport (CT): Praeger/Greenwood.

Turin, D (Ed.) (1975) *Aspects of the economics of construction*. London: Godwin.

Tversky, A (1969) Intransitivity of preferences. *Psychological Review*, **76**(Jan), 31–48.

Tversky, A and Kahneman, D (1986) Rational choice and the framing of decisions. *In:* R Hogarth and M Reder (Eds.) *Rational choice*. Chicago: University of Chicago Press.

Williamson, O E (1975) *Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization*. New York: Free Press.

Winch, G W (1989) The construction firm and the construction project: a transaction cost approach. *Construction Management and Economics*, **7**, 331–45.

Wong, J T-Y, Hui, E C-M, Seabrooke, W and Raftery, J (2005) A study of the Hong Kong property market: housing price expectations. *Construction Management and Economics*, **23**(7), 757–65.

APPENDIX A: LIST OF PAPERS INCLUDED IN TABLE 1 IN ONE OF THE TEN JEL 2-DGIT GROUPS WITH FOUR OR MORE CME PAPERS

[1] D2 Production and Organizations: 12 papers

D23 Organizational behaviour; Transaction Costs; Property Rights: 9 papers
Bridge, A J and Tisdell, C (2006, March) The determinants of the vertical boundaries of the construction firm: response.

Chang, C-Y (2006, March) The determinants of the vertical boundaries of the construction firm: comment.

Bridge A.J. and Tisdell C. (2004, October) The determinants of the vertical boundaries of the construction firm.

Costantino, N, Pietroforte, R and Hamill, P (2001, July) Subcontracting in commercial and residential construction: an empirical investigation.

Lai, L W C (2000, April) The Coasian market-firm dichotomy and subcontracting in the construction industry.

Wong, K-C and Walker, A (2000, March) Property rights implications of public-private joint ventures.

Rahman, M M and Kumaraswamy, M M (2002, January) Joint risk management through transactionally efficient relational contracting (could be also L14).

Winch, G M (2001, December) Governing the project process: a conceptual framework.

Sozen, Z and Kayahan, O (2001, March) Correlates of the length of the relationship between main and specialist trade contractors in the construction industry.

D24 Production; Cost; Capital and Total Factor Productivity; Capacity: 3 papers
Duncan, K, Philips, P and Prus, M (2006, June) Prevailing wage regulation and public school construction efficiency: a stochastic frontier approach.

Sumardi, R H and Anaman, K A (2004, September) Aggregate efficiency analysis of resource use and demand for labour by the construction industry in Brunei Darussalam.

Mao, Z, Goh, B H, Wang, S Q and Ofori, G (2003, October) Total factor productivity growth accounting in the construction industry of Singapore.

[2] D4 Market structure and pricing: 5 papers

D41 Perfect competition: 1 paper
Skitmore, M, Runeson, G and Chang, X-L (2006, July) Construction price formation: full-cost pricing or neoclassical microeconomic theory?

D44 Auctions: 4 papers
Liu, S L, Wang, S Y and Lai, K K (2005, May) A general multivariate analysis approach for determining bid mark-up strategy.

Skitmore, M (2004, January) predicting the probability of winning sealed bid auctions: the effects of outliers on bidding models.

Fu, W K, Drew, D S and Lo, H P (2002, November) The effect of experience on contractors' competitiveness in recurrent bidding.

Ngai, S C, Drew, D S, Lo, H P and Skitmore, M (2002, September) A theoretical framework for determining the minimum number of bidders in construction bidding competitions.

[3] D5 General Equilibrium and Disequilibrium: 4 papers

D57 Input-output Tables and Analysis: 4 papers
Dietzenbacher, E and Hoen, A (2006, July) Coefficient stability and predictability in input-output models: a comparative analysis for the Netherlands.

Song, Y, Liu, C-L and Langston, C (2006, June) Linkage measures of the construction sector using the hypothetical extraction method.

Wu, X and Zhang, Z-H (2005, November) Input-output analysis of the Chinese construction sector.

Pietroforte, R and Gregori, T (2003) An input–output analysis of the construction sector in highly developed economies.

[4] E3 Prices, business fluctuations and cycles: 5 papers
Hsieh, H (2005, March) The 1990s Taiwan residential construction boom: a supply side interpretation.

Wong, J T-Y, Hui, E, Seabrooke, W and Raftery, J (2005, September) A study of the Hong Kong property market: housing price expectations.

Chan, S-L (2002, September) Responses of selected economic indicators to construction output shocks: the case of Singapore.

Raftery, J, Csete, J and Hui, S K F (2001, March) Are risk attitudes robust? Qualitative evidence before and after a business cycle inflection.

Tse, R Y C and Raftery, J (2001, January) The effects of money supply on construction flows.

[5] F2 International Factor Movements and International Business: 4 papers

F23 Multinational Firms; International Business: 4 papers
Cuervo, J and Pheng, L S (2005, February) Significance of internalization factors for Singapore transnational construction corporations.

Pheng, L S and Hongbin, J (2004, March) Estimation of international construction performance: analysis at the country level.

Ofori, G (2003, June) Frameworks for analysing international construction.

Cuervo, J and Pheng, L.S. (2003, January) Ownership advantages/disadvantages of Singapore transnational construction corporations.

[6] G1 General Financial Markets: 11 papers

G13 Contingent pricing; futures pricing: 11 papers

Mattar, M and Cheah, C (2006, Aug) Valuing large engineering projects under uncertainty: private risk effects and real options.

Yiu, C-Y and Tam, C S (2006, May) Rational under-pricing in bidding strategy: a real options model.

Cheah, C and Liu, J-C (2006, May) Valuing governmental support in infrastructure projects as real options using Monte Carlo simulation.

Huang, Y-L and Chou, S-P (2006, April) Valuation of the minimum revenue guarantee and the option to abandon in BOT infrastructure projects.

Garvin, M J and Cheah, C Y J (2004, May) Valuation techniques for infrastructure investment decisions.

Ng, F P and Bjornsson, H C (2004, June) Using real option and decision analysis to evaluate investments in the architecture, construction and engineering industry.

Ng, F P, Bjornsson, H C and Chiu, S S (2004, February) Valuing a price cap contract for material procurement as a real option.

Ford, D, Lander, D and Voyer, J (2002, June) A real options approach to valuing strategic flexibility in uncertain construction projects.

Sing, T F (2002, March) Time to build options in construction processes.

Ho, S P and Liu, L Y (2002, March) An option pricing-based model for evaluating the financial viability of privatized infrastructure projects.

Boukendour, S and Bah, R (2001, October) The guaranteed maximum price contract as call option.

[7] L1 Market Structure, Firm Strategy and Market Performance: 5 papers

McCloughan, P (2004, November) Construction sector concentration: evidence from Britain.

Chiang, Y-H, Tang, B-S and Leung, W-Y (2001, November) Market structure of the construction industry in Hong Kong.

London, K A and Kenley, R (2001, December) An industrial organization economic supply chain approach for the construction industry: a review.

Ball, M, Farshchi, M and Grilli, M (2000, October) Competition and the persistence of profits in the UK construction industry.

De Haan, J, Voordijk, H and Joosten, G-J (2002, March) Market strategies and core capabilities in the building industry.

[8] L2 Firm Objectives, Organization, Behaviour: 4 papers

L25 Firm performance; size and scope; diversification: 4 papers
Phua, F (2006, March) Predicting construction firm performance: an empirical assessment of the differential impact between industry- and firm-specific factors.

Kreitl, G and Oberndorfer, W (2004, September) Motives for acquisitions among engineering consulting firms.

Cho, Y (2003, October) The organizational boundaries of housebuilding firms in Korea.

Kreitl, G, Urschitz, G and Oberndorfer, W (2002, July) Corporate growth of engineering consulting firms: a European review.

[9] O1 Economic development: 6 papers
Hosein, R. and Lewis, M T (2005, February) Quantifying the relationship between aggregate GDP and construction value added in a small petroleum rich economy – a case study of Trinidad and Tobago.

Yiu, C Y, Lu, X H, Leung, M Y and Jin, W X (2004, May) A longitudinal analysis on the relationship between construction output and GDP in Hong Kong.

Su, C-K, Lin, C-Y and Wang, M-T (2003, October) Taiwanese construction sector in a growing ‘maturity’ economy, 1964–1999.

Tan, W (2002, October) Construction and economic development in selected LDCs: past, present and future.

Lean, C S (2001, July) Empirical tests to discern linkages between construction and other economic sectors in Singapore.

Han, S S and Ofori, G (2001, March) Construction industry in China’s regional economy, 1990–1998.

[10] O3 Technological Change, Research and Development: 7 papers
Manley, K and Mcfallan, S (2006, Sept) Drivers of firm-level innovation in the construction industry.

Leiringer, R (2006, March) Technological innovation in PPPs: incentives, opportunities and actions.

Reichstein, T, Salter, A and Gann, D (2005, July) Last among equals: a comparison of innovation in construction, services and manufacturing in the UK.

Doree, A and Holmen, E (2004, October) Achieving the unlikely: innovating in the loosely coupled construction system.

Sexton, M and Barrett, P (2003, September) A literature synthesis of innovation in small construction firms: insights, ambiguities and questions.

Dubois, A and Gadde, L-E (2002, October) The construction industry as a loosely coupled system: implications for productivity and innovation.

Slaughter, E S and Shimizu, H. (2000, April) Clusters of innovations in recent long span and multi-segmental bridges.

BACKWARD AND FORWARD LINKAGES OF THE CONSTRUCTION SECTOR: AN INPUT–OUTPUT ANALYSIS AND THE BON CURVE IN THE CASE OF NORTH CYPRUS

Ozay Mehmet[1] and Vedat Yorucu

Department of Economics, Eastern Mediterranean University, Salamis Road, Famagusta, Cyprus

Relevant literature, especially the Bon curve, is used to document the dynamo role of the construction sector in North Cyprus on the basis of an empirical estimation of backward and forward linkages during the period 1998 and 2005. This was a period when the North Cyprus economy experienced an economic boom in the aftermath of the UN Peace Plan known as the Annan Plan for settling the Cyprus problem. The latest input–output table for the North Cyprus economy is 1998 and the authors had to derive backward and forward linkages for 2005 from a detailed breakdown of inter-industry transactions per unit of construction output using the most significant purchases and deliveries, normalizing these transactions for comparability between 2005 and 1998. The results reflect radically different patterns of inter-industry transactions in 2005 compared to 1998. The paper also has general interest in highlighting the possibility of a modified Bon curve for micro-states, such as North Cyprus, in which environmental constraints may be encountered earlier implying an inverted V-shaped Bon curve in place of a inverted U-shaped.

Keywords: backward linkage, developing country, environmental impact, forward linkage, input–output analysis.

INTRODUCTION

North Cyprus is a micro-state in the Mediterranean with a population of 256 644 (2006 Census) inhabitants and 3298km square land. Total GNP in 2005 was US$2327.8 million and per capita income was US$10 567 (State Planning Organization 2007). Input–output analysis is used to study empirically the explosive construction boom in the micro-state of North Cyprus. In 2006 the construction sector grew by over 35.2%, far in excess of the real GDP growth of over 13.5%, an explosive economic growth now in its third year. As explained in an earlier paper this boom is primarily triggered by the Annan Plan (2004) Referendum in May 2004 (Yorucu and Keles 2007) which aimed at ending political division in Cyprus. The implications of the Annan Plan for the construction sector have been discussed in a previous paper (Yorucu and Keles 2007). In a sense, this study is a sequel to the earlier one.

[1] ozay.mehmet@emu.edu.tr

The Bon curve presumes a two-stage secular relationship between construction volume and GDP which, in fact, is better broken down into three stages. In the first and early stage of economic development, a stage which may be called drive to maturity in line with Rostow's theory (Rostow 1956), construction growth exceeds the GDP growth rate and a steep positively sloped curve is reflected. In the second stage, both the GDP and construction reveal slower growth as the economy approaches a peak or 'maturity' stage. In the third and final stage, beyond maturity, the contribution of construction to GDP declines as other sources of growth (e.g. service oriented) emerge and overtake construction.

Although the existence of the Bon curve can be assumed generally, its shape is not yet settled. The exact nature of the construction–GDP relationship is a matter of empirical evidence and several questions of theory emerge over stages and transformations, over and above problems of statistics, sources and methodology. Thus, some question the slope of the Bon curve during the drive to, and beyond, the maturity stage. Thus, as economies 'mature', construction activity slows down and the declining portion of the Bon curve becomes flatter, indicating a declining importance of the construction sector in the economy. (This observed slowdown may also be due to the omission in official statistics of such construction innovations as fire alarms, security and internet installations.) Pietroforte and Gregori (2006), using Danish data, have verified this 'slowing down' of construction since the mid-1970s. Su *et al.* (2003), using data over 1964–99, have similarly found that Taiwanese construction, after rapid growth since 1969, declined after 1981.

The Bon curve also raises desegregation issues. Within the aggregate relationship revealed by the Bon curve, there are important transformations because the construction sector is a diverse sector, consisting of residential, institutional, commercial, industrial and other sub-divisions. During the course of economic development, the relative significance of these construction sub-sectors is altered in tandem with the Colin–Clark hypothesis (Mehmet 1999: 96) that with a rising GDP, the structure of the economy changes from being agrarian to industrial and then to service-based economic activity. Pietroforte and Tangerini (1999), using disaggregated Italian data for the 50 largest firms, have demonstrated that during 1980s and 1990s these firms have responded to changing industrial policy to adopt a service orientation in construction activity in order to remain competitive.

In micro-states, where the land constraint is encountered earlier compared to large economies, the drive to maturity appears to entail a shorter timeframe. This evidence confirms the Bon curve, but it suggests that the shape of the curve may be more like an inverted V rather than a U-curve. In order to escape the limiting land factor, micro-state construction has developed some innovative solutions such as vertical construction or going transnational. In the case of Singapore a 'transnational construction' specialization has developed (Cuervo and Pheng 2003), providing specialized and innovative construction services beyond Singapore's own boundaries, in nearby ASEAN neighbouring countries and beyond. Singapore's land constraint has also been partially overcome by means of an international 'growth triangle', whereby surplus capital has been utilized to acquire land from neighbouring Malaysia and Indonesia for development of huge industrial estates and export processing zones.

In Hong Kong, construction has gone 'vertical' with the majority of buildings coming into the 'multi-storey category' (Picken and Ilozor 2003). A further characteristic of Hong Kong construction is the role of expectations in price volatility, partly caused by financial factors and partly political linked to Hong Kong–Chinese relations (Wong *et al*. 2005). Political factors, specifically the Iraqi invasion under Saddam have also been a dominant factor behind construction in the oil-rich state of Kuwait.

FORWARD AND BACKWARD LINKAGES, 1998–2005

This part of the research documents the explosive construction growth in North Cyprus against the macroeconomic climate of the country.

According to the State Planning Organization (2005) construction growth expansion is strictly post-2002. The date is important because it reflects the onset of macroeconomic stability in reform when strict IMF-inspired reforms suddenly and significantly reduced inflation and interest rates and stabilized the value of the Turkish Lira. The results in North Cyprus of these macroeconomic reforms were immediate and laid the basis for a huge construction take-off after 2002. In the pre-reform period 1997–2001, the GNP in constant prices was virtually stagnant, growing merely at an average of 1.8%, in fact actually declining in 2000 and 2001. During 2002–06, the GNP growth rate jumped to an average of 11% per annum.

Construction played a key role in this economic transformation. Prior to economic reforms in Turkey, in 1997, the construction sector accounted for 8.1% of the GNP; 10 years later in 2006, this share jumped to 12%, becoming the second largest sector after trade/tourism, which includes wholesale and retail trade and hotels and restaurants. The construction growth rate, which during 1997–2001 was a mere 1.9% per annum, exploded to an average growth of 21.2% during 2002–06.

BACKWARD LINKAGES

Backward linkages in this paper relate to direct input interdependence between the construction sector and other sectors. Put differently, they refer to purchases by the construction sector of intermediate goods in inter-industry transactions. These input purchases, priced at producer prices, are the fixed coefficients indicating required amounts per unit of construction output.

In 1998, when the construction sector was stagnating as did the entire North Cyprus economy, the principal source of intermediate inputs for the construction sector was sub-sector 5 (manufacture of cement, lime and plaster-related articles) with 0.218 coefficient value, followed by sub-sectors 6 (manufacture of basic precious and non-ferrous metals) and 7 (wholesale and retail trade, sale, maintenance and repair of motor vehicles) with the second (0.142) and third (0.193) highest coefficients.

Table 1: Backward linkage coefficients, 1998 and 2005 (State Planning Office 2005)

Sub-sectors		1998 Coefficients*	2005 Coefficients*
1	Quarrying of stone, sand and clay	0.106	0.017
2	Manufacture of wood and products of wood and cork	0.043	0.137

3	Manufacture of other chemical products	0.042	0.015
4	Manufacture of ceramic products, cutting & finishing of stone & man	0.078	0.022
5	Manufacture of cement, lime and plaster-related articles	0.218	0.214
6	Manufacture of basic precious and non-ferrous metals	0.193	0.079
7	Wholesale and retail trade, sale, maintenance and repair of motor vehicles	0.142	0.182
8	Financial intermediation, except insurance and personal banking	0.055	0.331
9	Others	0.123	0.003
	Total inputs (billions of TL)	18.085	943.675
	Final demand (billions of TL)	13.565	2126.7
	Total construction output (billions of TL)	31.65	3070.3

Notes:
Values in producer prices.
*Formula: Sub-sectoral value divided by total construction output less final demand.

In 2005, sub-sector 7, the source of investment funds became the leading provider of inputs for the construction sector while the cement and related sub-sector 5 dropped to second rank with 0.214 coefficient value. The wholesale and retail trades, involving motor vehicles, kept their third rank (0.182), while the wood products sub-sector 2 moved up from eighth (0.043) to fourth (0.137) rank.

There were significant changes in the coefficients themselves. Thus, whereas in 1998 one unit of output required just 0.055 units of input from the financial sub-sector, in 2005, this coefficient rose to 0.33; in other words, the production of construction output in North Cyprus became significantly driven by availability of finance. Equally significantly, construction output became more than three times more wood intensive; the use of wood inputs per unit of construction output rose from 0.043 to 0.137. On the other hand, if we take the sub-sector as an indication of capital intensity, there was hardly any progress, presumably a reflection of the availability of cheap wage labour imports from Turkey. We were unable to calculate the import of primary labour input due to lack of necessary input–output breakdown. However, it is an observable fact that North Cyprus construction is heavily dependent on cheap wage labour imports from the Turkish mainland.

FORWARD LINKAGES

Similar to backward linkages, forward linkages relate to deliveries of construction outputs to other sectors, as intermediate goods, plus final demand components. The forward linkage coefficients represent how much the construction sector delivers to other producers and final demand users per unit of output.

Table 2: Forward linkage coefficients, 1998 and 2005 (State Planning Office 2005)

Sub-sectors		**1998 Coefficients***	**2005 Coefficients***
1	Wholesale and retail trades	0.056	0.458
2	Hotels and bungalows	0.512	0.207
3	Restaurants and bars	0.170	0.002
4	Construction	0.000	0.000

5	Financial intermediation	0.242	0.136
6	Other services	0.020	0.197
		1.100	
	Total inputs (billions of TL)	30.594	437.18
	Final demand (billions of TL)	31.694	506.44
	Total construction output (billions of TL)		943.62

Notes:
Values in producer prices.
*Formula: Sub-sectoral value divided by total construction output less final demand.

It will be observed from Table 2 that significant changes occurred during the explosive growth period under review. Whereas in 1998 hotels and bungalows (for alternative tourist accommodation) represented the top intermediate users of construction output (0.512), by 2005 this sub-sector was overtaken by the wholesale and retail trades (0.458). The third rank in 2005 belonged to other services, which are institutional types of users (0.197), e.g. hospitals, schools, which in 1998 were relatively insignificant (0.020).

One important aspect of construction in North Cyprus is the fact that outputs are primarily delivered for final demand users, intermediate users accounting for a much smaller share of total sector output. In 1998, no less than 96.5% of the total construction output went to final demand users. Although in 2005 this share dropped to 53.7%, which is a very large decline, final demand components were collectively still ahead of intermediate consumption. Within the final demand component, by 2005 private fixed capital formation was significantly outstripping the public share, in complete reversal of the position in 1998. In other words, by 2005, private sector demand became the driver of the construction sector activity.

ENVIRONMENTAL DEGRADATION

Explosive construction growth in North Cyprus has been largely unplanned and is now encountering environmental limits. As reported in Yorucu and Keles (2007), there is a fundamental conflict between private gain and public net benefit. A hot and highly profitable property market has attracted a large number of speculative investors and contractors pursuing private profit with no concern for the unique ecology of North Cyprus. In the process, the natural assets on the shoreline and mountains are being depleted, while infrastructural constraints are encountered with inadequate roads, electricity and water resources.

Government authorities have finally acted vigorously in 2007 in order to protect the public interest. Two actions have been taken. One is a sharp increase in the rates of property taxation. Since colonial times, property taxation in North Cyprus has been minimal and this has starved municipalities and local government authorities of much needed revenue to provide essential services and protect the environment. The problem has been well noted in a recent World Bank report (World Bank 2006) which recommended a significant increase in property tax rates. The Ministry of Finance has acted and introduced a threefold increase in property taxes to take immediate effect.

The other major policy action was the enactment of Cabinet decrees (TRNC Official Gazette 2006) putting a temporary ban on construction licences in the fragile Five Fingers Mountain Range in order to protect the watershed and the ecology of the area.

This is the latest amended Cabinet decree (TRNC Official Gazette 2007) for Kyrenia, supplementing earlier similar measures for Karpaz Peninsula in 2005 (TRNC Official Gazette 2005a) and for eastern (Tatlisu and Karpaz) and western Kyrenia (Akdeniz) coastal region in 2004–05 (TRNC Official Gazette 2004, 2005b and 2005c). These decrees have had the predictable negative impact on the construction sector. This means that the rate of growth of construction may not be at the 35% level observed last year, but it may fall to a rate that is much more sustainable in the long run. If demand continues for North Cyprus property at levels observed during the boom period, the impact of the Cabinet decree may be higher prices and better quality of construction as investors and property owners are obliged to pay greater attention to public interest in the protection of the environment.

CONCLUSION: A MODIFIED BON CURVE?

The ecological limit observed in North Cyprus has a significant implication for the shape of the Bon curve. It suggests that in micro-states with land constraint and access to cheap labour supply, the expansion portion of the Bon-curve may be steeper, the peak much more pronounced and the declining portion relatively flatter compared to the Bon curve. The steeper portion of the curve mirroring explosive construction growth in North Cyprus has been shown to be unsustainable and it is already being checked by tougher environmental and land zoning standards. The rate of decline in the downward portion of the curve is the function of political commitment in the implementation of the standards.

There is also an important theoretical implication emerging from our results. It is the suggestion that in the case of micro-states with a fragile ecosystem, such as North Cyprus, construction growth may be limited not by an inverted U, as predicted by the Bon curve, but rather by an inverted V. In other words, construction in micro-states may rise and decline at a much faster rate than in larger countries. In the case of Singapore and Hong Kong vertical construction growth may have a delaying impact, as noted in the literature. In the case of North Cyprus where vertical expansion is not an option, environmental limits are encountered much sooner and government authorities are then obliged to step in to protect net public benefit putting the brakes on explosive construction growth. Cabinet decrees discussed above are reflections of this limiting fact.

The inverted V hypothesis advanced here does not invalidate, but merely modifies, the Bon curve. It suggests that some sort of reconciliation between quantity and quality of construction activity occurs earlier in micro-states with fragile ecological assets, but, of course, the ‘lessons’ evident here have universal implications. What is suggested is that rapid construction growth has to be placed on a long-term sustainable footing to ensure that construction growth does not get out of control causing irreparable environmental degradation. The risks of such degradation being much higher in micro-states such as North Cyprus, the case for closer public scrutiny of construction activity is greater.

REFERENCES

Annan, K (2004) Comprehensive settlement of the Cyprus problem. UN Official Paper, 31 March, New York.

Cuervo, J C and Pheng, L S (2003) Ownership advantages/disadvantages of Singapore transnational construction corporations. *Construction Management and Economics*, **21**(1), 81–94.

Mehmet, O (1999) *Westernizing the Third World, Eurocentricity of economic development theories*. London and New York: Routledge.

Picken, D H and Ilozor, B D (2003) Height and construction costs of buildings in Hong Kong. *Construction Management and Economics*, **21**, 107–11.

Pietroforte, R and Gregori, T (2006) Does volume follow share? The case of the Danish construction industry. *Construction Management and Economics*, **24**, 711–15.

Pietroforte, R and Tangerini, P (1999) From boom to bust: the case of Italian construction firms. *Construction Management and Economics*, **17**, 419–25.

Rostow, W W (1956) The take-off into self-sustained growth. *Economic Journal*, **66**(March), 23–48.

State Planning Organization (2005) *Kuzey Kıbrıs Türk Cumhuriyeti Ekonomik ve Sosyal Göstergeler (Economic and social indicators, TRNC)*. Nicosia: KKTC Başbakanlık, DPÖ İzleme ve Koordinasyon Dairesi.

State Planning Organization (2007) *Kuzey Kıbrıs Türk Cumhuriyeti Ekonomik ve Sosyal Göstergeler (Economic and social indicators, TRNC)*. Nicosia: KKTC Başbakanlık, DPÖ İzleme ve Koordinasyon Dairesi.

Su, C K, Lin, C Y and Wang, M T (2003) Taiwanese construction sector in a growing 'maturity' economy, 1964–1999. *Construction Management and Economics*, **21**, 719–28.

TRNC Official Gazette (2004) Urban Development Law, 55/89. *Decree on Karpaz*, 12 August, No. 118.

TRNC Official Gazette (2005a) Urban Development Law, 55/89. *Decree on Karpaz*, Amended copy for Tatlisu and Buyukkonuk, Special Issue No. 2, Part III, 19 August, No. 142.

TRNC Official Gazette (2005b) Urban Development Law, 55/89. *Decree on Akdeniz-Kyrenia*, Special Issue No. 2, Part III, 19 August, No. 142.

TRNC Official Gazette (2005c) Urban Development Law, 55/89. *Decree on Karpaz*, Amended copy for Tatlisu and Buyukkonuk, Special Issue No. 2, Part III, 25 October, No. 157.

TRNC Official Gazette (2006) Urban Development Law, 55/89. *Decree on temporary period for Girne*, Special Issue, Part III, 16 November, No. 192.

TRNC Official Gazette (2007) Urban Development Law, 55/89. *Decree on Girne*, Special Issue, Part III, 30 January, No. 17.

Wong, J T-Y, Hui, E C M, Seabrooke, W and Raftery, J (2005) A study of the Hong Kong property market: housing price expectations. *Construction Management and Economics*, **23**, 757–65.

World Bank (2006) *Sustainability and sources of economic growth in the northern part of Cyprus*, Feasibility studies for economic development projects, 8 June, Report by the Poverty Reduction and Economic Management Unit, Europe and Central Asia Region.

Yorucu, V and Keles, R (2007) The construction boom and environmental protection in Northern Cyprus as a consequence of the Annan Plan. *Construction Management and Economics*, **25**(1), 77–86.

PROMOTING INNOVATIVE TECHNOLOGIES IN THE HOUSING SECTOR IN THE UK

Yamuna Kaluarachchi and Keith Jones

School of Architecture & Construction, University of Greenwich, Mansion Site, Bexley Road, Eltham, London SE9 2PQ, UK

The UK government has been advocating the implementation of innovative technologies to improve the sustainability of the built environment. It has the potential and strength in developing construction research in design and engineering, but the impact of these processes seems to be slow in reaching the residential sector. Given the large stock of existing dwellings, the situation is compounded, by issues related to climate change, to the point that this problem can no longer be ignored and requires an urgent response from all sectors involved. This paper attempts to highlight some of the key issues that are important in implementing innovative technologies in the housing sector. It briefly looks at the process of innovation in housing and presents lessons learnt from two research projects. The drivers and barriers and the role played by the government are examined in relation to the housing context. Economic benefits, improved performance, increased markets and organizations and their structure can promote innovation while funding, fear of risk, strict legislations, socio-cultural issues and mindsets of stakeholders can play a major role in hindering innovation in the residential sector.

Keywords: innovation, housing, sustainability, environmental technology, risk.

INTRODUCTION

The UK government has been advocating the employment of innovative technologies in the built environment for more than a decade. In its Sustainable Development Action Plan (Defra 2005), one of the key policy commitments is the “Implementation of actions arising from Climate Change Review” by Stern (2006). Stern states that the first essential element of climate change policy is carbon pricing, followed by technology policy, which is vital to bring forward the range of low-carbon and high-efficiency technologies that will be needed to make significant cuts in emissions. Policies to remove the barriers to behavioural change are stated as the third critical element. In addition, “research and development, demonstration and market support policies can all help to drive innovation and motivate a response by the private sector”. This timely review highlights the importance of incorporating innovative environmental technologies in all sectors and industries in reducing the impact of climate change.

Innovation in the current context has to incorporate issues of social, environmental and economic sustainability, where quality of life issues are given a high priority. Awareness of climate change and the adaptations of building stock have to play a key role in the environmental agenda. While some European countries and countries like Japan move forward by bringing their sustainability agenda to the public sector, the UK seems to be slow in embracing these ideas. A number of reviews of the construction industry provided waves of re-structuring and re-inventing, but long-term sustainability in improved products and processes for better performance, efficiency and innovative application of renewable and low carbon technology serving the built environment is yet to come. While funding remains a major constraint there are many other issues that directly or indirectly influence this process.

The UK has a fairly mature building stock which must be taken into account if a significant change in environmental performance is to be achieved. New buildings only add between 1–5 % of the total building stock each year (Wigginton *et al*. 2002). Intelligent application of advanced ‘smart’ facade technology in conjunction with innovative environmental systems can result in significant energy savings and – at the same time – improvement of indoor comfort. Kragh (2001) claims “It has been shown that, when designed carefully, innovative systems do not represent additional initial building costs. Running costs are lower and energy costs can be reduced by approximately 30% compared with conventional solutions”. The UK has strengths and further potential in developing construction research, design, engineering and project management, but the impact of these processes do not seem to be reaching a majority of players in the housing sector. The intention of this paper is to highlight some key issues that are important in implementing innovative technologies in the housing sector. It briefly looks at the process of innovation and its status in the housing context and presents lessons learnt from two research projects to illustrate factors that promote or hinder innovation. The discussion also examines the role played by the government in focusing attention on new opportunities for innovation, as well as on the barriers and constraints set by legislation. It is not within the remit of this paper to present the methodology, data and results of the research projects in detail, although some relevant findings are presented to illustrate and highlight some of the issues discussed.

THE INNOVATION PROCESS

The innovation process is defined by experts as “the successful exploitation of new ideas” (Dodgson *et al*. 2006), and which results in “enhanced performance and delivers objectively new or improved services to the user” (Seaden 2005). Recent authors have stated that “innovation is not a discreet or entity, but a socially mediated process that results from, and contributes to, a range of systemic relationships and interdependencies” and “from organizational, managerial and individual practices and decisions” (Dodgson *et al*. 2006). Their view of innovation is as a socially constructed and not technologically determined process, noting by way of introduction that “innovation is, and will remain, a socially determined and hence unpredictable process” and concluding that “technological change requires associated social, organizational and managerial changes”. There is also a consensus that innovation is risky, requires significant investment and is often resisted within firms (Seaden *et al*. 2003).

Innovation is often categorized according to whether it involves the development of a new product – by a new or established technique – or the introduction of new processes for producing an established product (Livesey 1983). While many people associate innovation with major technological or organizational advances, the vast majority of successful innovations result from a stream of small incremental changes that may individually have only limited effects on consumer behaviour (Foxall 1984). Organizational growth can also encourage innovation, as the number of product or service lines increases and existing products at various stages of their life cycle evolve. The consensus of an international Symposium on Construction Innovation in Ottawa was that innovation is becoming the principal tool to achieve greater market penetration and increased profitability, which was echoed by a study in Chile, where innovation is driven by increasing client's requirements, greater market competition and globalization (Serpell *et al*. 2001).

An ability to manage innovation as part of the overall corporate strategy is as important as the innovation itself. An organization's response to innovative ideas and its ability to transform them into viable products is influenced by its organizational structure and culture. These include a fear of change, or the disruptive impact of innovation on existing organizational hierarchies, work processes or management structures. Managing innovation essentially involves mediating between external forces for change and internal forces for stability. Innovation is rarely constrained within the boundaries of individual firms (Dodgson 1994). Firms learn both from their own experience of design, development, production and marketing and from a wide variety of external sources (Freeman 1991).

INNOVATION IN THE HOUSING INDUSTRY

Innovations in the built environment are often a complex blend of government, business, market and consumer decisions. In the housing sector, the homeowner or tenant is the ultimate user, but often is not involved in the decision, except through other agents (housing associations, builders and government) who purport to act in the future occupant's interest. Consumers also rely on the government for protection against failures in the system. Building material and process failures are extremely expensive to correct and can easily damage the financial position of consumers, as well as severely diminish their personal satisfaction with their homes. Given the problems facing building innovations (risk, invisibility, uncertainty, cost of failure and correction, 'trialability', and difficulty in establishing relative advantage in the short term) consumers probably expect government and building officials to be conservative in their acceptance of innovations. Reducing risk may be as important to homebuyers as cost savings. If so, time-honoured technologies and processes will not be abandoned without ample evidence that their replacements will perform as expected. This socio-cultural fear of change and risk is deep rooted, difficult to change and forms a major barrier in bringing innovation to the housing sector. Information sharing and responsive communications can contribute in combating these fears.

"The housing industry has long been recognized for its seeming resistance to change and is widely seen as being slow to produce or embrace technological innovations" (Koebel 1999). Market interventions promoting new construction date back to the immediate aftermath of World War II. Mass production techniques were promoted in Europe to overcome the enormous housing shortages left by the devastation of war. Public housing construction in the United States pursued similar technological fixes in producing low-cost housing. However, the results of those particular innovations were sterile environments that grew increasingly unproductive as occupancy demands shifted.

The main rationale for innovation in the housing industry is economic benefits related to cost reduction and quality improvements. Other rationales include tackling environmental and structural problems and achieving public policy objectives. The rationale for government support of innovation in the housing industry focuses on the social and economic importance of housing. It acknowledges the value of innovation and the social benefits to be obtained from improved industry performance and the need for government funding in order to offset the industry's characteristic underinvestment in innovation activities. As evident from the results in Case Study One, government support can be crucial for innovative projects to sustain their investment in a competitive housing market.

An environmentally sensitive and sustainable residential development requires houses that are more durable, energy efficient and less wasteful of land and material resources. These objectives cannot be achieved without advances in technology: “Sustaining sustainability requires innovation in technology, new materials, new products, and new processes, and adoption of innovation in building” (Koebel 1999). This process can be easily adopted in new construction, where technological advances can be introduced into the built environment at an early stage of the project. But the complex problem lies with the existing built environment. In the UK, the existing housing stock greatly exceeds the mass of the newly built dwellings. For a variety of reasons, retrofitting and renovating solutions are more complex than new-build ones, but these are unavoidable if sustainability challenges are to be met. Case Study examples from Research Project 2, Sustainable Urban Environments, illustrate that very little innovative environment technologies are implemented in the refurbishment of the existing housing stock. While initiatives such as the ‘Decent Homes Programme’ (DETR 2001) is intended to improve the environmental performance of dwellings, they sometimes achieve the opposite results, as housing authorities treat these schemes as vehicles for obtaining more funding rather than achieving sustainable dwellings. Research shows that when there are opportunities to employ new and innovative technologies in refurbishment, housing authorities implement basic or out-of-date technology to update their stock due to tight budgets and fear of risk (Green Street, Sustainable Homes 2003).

A number of authors (e.g. Gann 1996) have argued that some of the challenges in new-built housing could be met if house builders learnt lessons from the manufacturing industry, such as the construction of housing from a number of interchangeable component sub-assemblies. This type of approach would require a radical reorganization of the housing supply system, with component manufacturers and end-users playing a much larger role in the design process, and reorganized supply chains. Research Project 1: Monitoring Egan Compliance illustrates some crucial lessons learnt in such an initiative. Unless there is a high level of demand, the investors cannot sustain the initial capital costs required in factory-based production. The level of demand depends on many different criteria including cost, market forces, affordability and subsidies. In many cases, demand also depends on the degree of confidence in the product, the trust and the fear of taking risks by trying out new products and systems. The failure of large-scale change in homebuilding notwithstanding, technology innovations have been introduced and adopted within the industry. For example, manufactured housing now contributes a significant portion of total residential construction.

LESSONS FROM TWO RESEARCH PROJECTS

Project 1: monitoring an innovation programme to examine Egan compliance in social housing in the UK (2001–4)

Project 1 monitored a consortium of Register Social Landlords (RSLs) established to provide high-quality housing designed and procured in line with the principles set out in the Egan Agenda (1998). A strategic partnering arrangement was set up with a single contractor who developed an award-winning, modern, pre-fabricated timber frame housing system and built a customized factory production unit. It was an opportunity to monitor and record the performance of 28 housing development projects and the roles played by a complex team network in contributing to a strategic partnering agreement. As the RSLs agreed to procure 2000 new house units over a four year period (2001–5), a research project was set up to exploit this opportunity to study a major innovation programme and identify what key lessons could be learnt. The selected contractor was the subject of several takeover bids by rivals and experienced a number of problems with both, the supply of the timber frame housing system and site personnel, which compromised the quality of construction and resulted in a high turnover of site-based operatives. This, together with other problems (outlined below) meant that the volume of demand initially forecasted never materialized.

The main aim of the research was to set, monitor and compare the Key Performance Indicators (KPIs) and map the cause and effect relationships within the change programme. The details of the research methodology, data and analysis are beyond the realm of this paper and are to be published elsewhere (Kaluarachchi *et al*. 2007, under review). A brief summary is presented below.

Research methodology

The research methodology was based on case study monitoring and action research, developing a data collection and management of information system that could monitor the impact of the consortium's approach on the principles outlined in the Egan Agenda. Relevant KPIs, benchmarks and a data collection and site monitoring system were developed by the research team. A range of questionnaire surveys, detailed interviews with key project personnel, examination of site meeting notes and general feedback reviews were undertaken to identify good and bad practices associated with each project. An attempt was made to identify the softer, qualitative issues that are difficult to handle with normal numerical data collection methods.

Key lessons learnt from the initiative:

- All parties needed to be committed to the innovation programme. Failure to recognize the dynamics of the situation and, in particular, to deliver against the expectations of all parties, results in a breakdown of trust and confidence between partners.
- The level of demand required to sustain the contractor's performance should be ensured. In this instance, the contractor invested heavily at the inception of the project hoping to recover the capital costs as the projects progressed. The demand created did not justify the upfront investment and the market did not provide the opportunities that were expected. All the risk and loses had to be absorbed by the contractor. Risk management processes needed to be in place prior to commencing the project.
- Innovative procurement processes requires a change in mindset at all levels within the organizations. Effective mechanisms should be put in place to ensure that everyone understands the joint goals and know their part in the overall process. Training was identified as an essential ingredient in this process. The lack of familiarity with the innovative approach illustrated the need for formal training for all project managers, prior to commencement of new projects. There was also the need for support systems in terms of knowledge and information to be in place for frontline staff.

- Communication and co-ordination, which lead to continuous improvement of services and products, emerge as some of the key drivers for the successful delivery of quality social housing that meet both time and cost targets.
- Even though the government encourages initiatives, such as that monitored in the research study, there is little flexibility in support systems to assist in sustaining them.

Project 2: stakeholder consultation for sustainable urban environments project (SUE_IDCOP, 2004–7)

The SUE-IDCOP programme is responsible for providing the fundamental knowledge to underpin the improved sustainability of existing buildings. The overarching aim is to find ways to improve the performance of existing building envelopes that reduce the consumption of non-renewable resources over the whole building life cycle in a way that is economically viable and socially acceptable. Such facades could also provide performance data that could reduce the levels of waste associated with its maintenance and refurbishment. At the same time, energy and pollution would be minimized.

There are many innovative environment technologies that are readily available in the market. Case study examples here in the UK and extensively throughout Europe show that these technologies can be used effectively and economically in new build housing. In the UK, there is very little evidence of their use in routine maintenance and refurbishment. The UK construction industry, mainly the residential sector, seems to be cautious and slow in implementing these technologies. The current data on refurbishment illustrate that very basic building technology, sometimes unsustainable, is used to upgrade the dwellings.

As part of the ongoing research, two stakeholder consultations were undertaken. In this paper, only the results from these two consultations are presented.

Consultation 1: a pilot study of six major housing associations to identify barriers in promoting innovative environment technologies in refurbishment

The aim was to identify and review the barriers that stakeholders face in promoting innovative environment technologies in social housing refurbishment. The consultation was carried out in relation to three sectors in the procurement of social housing; management, development and the maintenance sector. It was considered under the following criteria: energy performance, water performance, waste management, durability and flexibility (whole life performance), and health and well-being of tenants (quality of life issues).

The results illustrated that:

- Value for money is a major governing factor. The benefits should outweigh the costs incurred. The RSLs work on a tight budget and unless it is proven that the benefits outweigh the capital cost, none of the new technologies are considered for implementation. The capital costs of most of these technologies are significantly higher than the available budgets and the potential cost savings in utility bills. The tangible benefits of employing renewable technologies are usually long-term and do not result in quick savings.
- The technology should be proven and fully demonstrated.
- There are quite a lot of products and systems in the market but very little information about their long-term performance, durability and ways in which

they can directly reduce cost. More information about whole life performance and cost savings is needed and should be made available to the RSLs.

- Confidence levels in the new products are low due to high costs in demonstration projects.
- Organizations are reluctant to take the risk.

Consultation 2: stakeholder engagement regarding sustainable refurbishment
A stakeholder consultation workshop conducted with 50 members of an RSL ready to embark on a sustainable refurbishment programme showed that current building technology applied in refurbishment of dwellings is basic. The group consisted of managers, technical officers and neighbourhood officers. Asked the question "What are the environmental technologies that can make a real difference in tenants' life?", 100% of the respondents listed double glazing and efficient heating as their first priority and insulation as second. This illustrates the problem that is faced by current stock in failing in thermal comfort. The responses are related to alleviating fuel poverty, which is a basic requirement rather than embark on a radical refurbishment of the existing stock to the current building standards. Implementation of renewable technology measures was stated by three groups at varying levels of priority, but not a criterion listed by the decision makers (managers) as important.

All participants agreed that the number one criterion that acts as the barrier in implementing these sustainable technologies is a purely financial one, "initial cost, value for money and long payback periods". By popular consensus, "tenants' attitude, lack of interest, fear and behaviour" came as the number two criterion. Three groups agreed that the 'structure of organization' also play a key role in this process and cited it as their number three barrier. A lack of maintenance staff, reluctance to take risks, politics and legislation were also cited as other barriers.

When presented with the question "Criteria that influence the decision making process in allocating resources", the managers' group came up with a list that they thought best illustrated the crucial criteria and stressed the fact that funding issues span and govern all the other criteria as a major issue. The main criteria tabulated were:

- Statutory requirements, achieving government targets, tenant interest requirements, good value for money (payback period, options), annual budget, speed of delivery and lease holder tribunals.

Justification of resources; issues pertaining to increasing rent to recover the capital costs and the constraints held by tenant tribunals in challenging each of the RSLs decisions regarding improvements to the housing stock, were also stated as deterring implementation of any innovative ideas.

DISCUSSION: FACTORS THAT AFFECT INNOVATION

Factors that affect the implementation of innovative technologies define the context in which the industry operates. The globalization of markets, increased environmental requirements, higher consumer expectations and increased competition are examples of such factors and normally lie beyond the control of these organizations. "Three sets of factors that affect innovation and are controllable constitute elements to develop strategies to foster more innovation in housing. They are referred to as innovation accelerators, innovation barriers and contingent factors (factors which can foster or impede innovation, depending on how they are managed or implemented)" (National Research Council of Canada 2002).

The first major reason for innovation is economic benefit. This can be reflected in various ways, such as increased profit, increased market share and business growth. Another reason for innovation is remedying problems that result in better performance and related economic benefits. Increased investment in research and development of products and services can facilitate innovation and better performance. A third reason for innovation is to achieve public policy objectives, such as energy conservation. The public policy rationale for energy conservation may well be environmental preservation; the private sector rationale may be reducing operating costs of homes or businesses and making profits by marketing improved products. The housing consortium monitored in research project 1, was set up to achieve a 'better performance at an affordable cost using factory production techniques' as was advocated in the Egan agenda.

Organizations and their structure have a major influence in the innovation process. Visionaries who have corporate influence can drive innovation and influence the market growth, but will need support from other organizations in stabilizing the process and creating the demand that is needed to establish the market. Developing a culture of innovation in organizations and industry appears to be vital in triggering innovation. The main driving forces are the ideas of stakeholders, i.e. customers, management, marketing personnel and production personnel, as they focus on problem fixing and developing new ideas. Project 1 was set up solely by a visionary who wanted to achieve real change in the social housing sector. But as the lessons from this experience show, the organizational structure and the support that was needed to facilitate such an initiative was not present. The commitment of all parties, a changed mindset at all levels and better communications between all levels were crucial requirements to make the initiative a success.

The housing industry has a serious shortage of skilled labour. A skilled workforce is critical to an organization's ability to innovate. Training and education are essential in the development of a skilled workforce. In Project 1, the contractor experienced many problems due to his inability to retain skilled workers. The lack of demand for the houses (mainly due to rival takeovers) slowed down the factory production and affected the retention of staff, which in turn affected the quality of the product. Poor quality products resulted in losing the trust and confidence of the consortium members and reduced the demand that was originally envisaged.

Research, development and increased patronage by the government and other funding agencies can drive innovation. International competitiveness and increased and improved access to domestic and international markets can also have a positive influence on innovation.

Risk is one of the main barriers to innovation. Innovators face many types of risk, including performance failure, market rejection, delayed or non-approval by regulatory authorities, rejection by trades/labour and liability. All of these risks have an associated potential financial loss, and the trend is towards increasing risk, particularly risk of liability. Results from the stakeholder consultations showed that many housing organizations are reluctant to implement innovative technologies due to fear of taking risks, and consider implementing only basic technology in their refurbishment programmes. A snapshot of case studies given in Green Street (Sustainable Homes 2003) illustrates the current status of refurbishment and the savings that can be achieved with the most basic environmental upgrades in the short term. In many examples (Case study Sandwell, Green Street), refurbishment costs about 15% higher than for comparable conventional housing are considered a worthwhile investment, due to the fact that maintenance costs are likely to be much lower than for traditional council homes.

Financing innovation has always been a key problem. Small and medium companies find it hard to invest in research and development and hence break into new markets due to financial constraints. Research Project 1 shows that, in some instances, there are considerable upfront capital costs, but increased consumer demand and a greater market share will contribute to recover these costs. In Project 2, the housing associations were reluctant to spend the initial capital cost required, without having guarantees that they will be recovered within a limited time. Usually in the housing sector, developers are also wary of implementing new technologies because of fears about consumer preferences. Consumer demand affects the supply and market investors and stock market analysts become concerned about investment in new techniques or products which may be regarded as risky. Project 1 showed that without sufficient demand, a new initiative could not sustain itself. Lack of consumer demand coupled with the inflexibility of building regulations and regulation administrators are commonly regarded as detrimental factors for innovation.

The housing industry is heavily regulated by national and local regulations governing land use and planning, infrastructure and buildings. Literature reviews, experiences from the housing industry and research indicate that regulations are a major barrier for innovation. In particular, factors such as lack of mandate to accommodate or foster innovation at the local level, and lack of empathy by local building officials to accommodate innovations, are detrimental to the process. It is the availability of incentives that promotes innovation. These incentives could be of various forms, such as tax or VAT refunds and targeted funding and support. Some incentives, such as compensation to offset costs of training trades on how to incorporate innovations, may also be useful.

The social systems surrounding housing production resist change. This could be due to inflexible mindsets, socio-cultural values, or simply fear of change or taking risks. In order to achieve the full benefit of innovative technology, the user has to be familiar with its use. Educating the occupier is crucial to overcome these setbacks. Research carried out by Sustainable Homes (2003) showed that, given the right information and control, tenants are happy to implement new environment technologies in their dwellings. Savings in utility bills can be a major incentive in this process.

The Government’s role

The government and public policy makers might desire green, sustainable buildings and affordable housing, but they have few clear tools to achieve these within the current market. Governments can enhance or slow innovation processes. Despite governments advocating innovation, there is very little support to sustain the growth of innovation. In the past, government interventions were typically in the form of more regulations, which too often impeded the very progress desired. Local government enforces building regulations and is in a position to prohibit or enable building innovations. Advocates for adoption of building innovations have to change building codes to enable builders and/or consumers to adopt any favoured innovation.

Current policy in the UK identifies the experienced client as the main institutional leader in stimulating construction innovation, yet doubts remain regarding a client’s ability to play this role. Nam and Tatum (1997) show that a client needs to be technically competent in order to understand innovative proposals from systems integrators, and hence take the risk of innovating. From this perspective, a particular weakness of the British system is that the single most important client – the state – has no equivalent competency to assess innovative proposals, while many local authorities, private sector clients and privatized utilities have been outsourcing their architectural and engineering functions. The analysis of complex systems industries also suggests that more attention needs to be given to the two other elements of the innovation superstructure: the regulatory environment on the one hand, and the professional bodies, research establishments and universities on the other. “It is the way in which the professional institutions carried out their brokering role that sometimes slowed the innovation process, and it was this brokering that provided the basis for the new regulations” (Winch 1998).

The UK Government is committed to expanding its supporting programme for renewable energy technologies including research, development, demonstration and dissemination. The main current hurdle preventing large-scale manufactures of photovoltaic panels in the UK is the current market, or lack of it. The understanding and potential of photovoltaic technology is improving, but further research and development is required to achieve cost reductions. It is important that strong partnerships are established between industry and government. Increasing environmental concerns and the need to achieve emission reduction targets should help the technology to become further established as a marketable and economically viable product.

Government incentives in terms of tax benefits and funding can facilitate the innovation process. Clear government targets and patronage can make the residential sector embrace innovative strategies into practice. New innovative procurement methods and contractual reforms have to be introduced to achieve the targets set. Initiatives such as Partnering (PPC 2000), Private Public Partnerships (PPP) and Private Finance Initiatives (PFI) contractual agreements were introduced as a result of Latham (1994)and Egan (1998) reviews. If the UK government is to meet its CO_2 reduction targets, many innovative technologies have to be incorporated to the existing building stock.

CONCLUSIONS

The housing sector is slow to embrace technological innovation. Housing authorities are reluctant to introduce or implement innovative environment technologies in their housing projects due to the initial extra capital costs, fear of taking risks and lack of demonstrable examples. Research shows that many factors need to be overcome to make this process viable. The housing associations must consider the whole-life cost savings, as a way of recovering the higher initial costs in the long-term, and persuade their tenants to this way of thinking rather than settle for quick-fix solutions that are outdated. Savings in utility bills can be a good incentive to try to accommodate some of these sustainable technologies in the dwellings. Information sharing, responsive communication, training and personal control can contribute in assisting the tenants to adapt to these new technologies and processes.

The drivers of innovation are economic benefits, performance improvements, environmental upgrading, research, development and information and knowledge transfer techniques and access to markets. Governments can play an important role in the innovation process. Support mechanisms in terms of resources, incentives, providing opportunities and access for local and international markets, training and information sharing mechanisms all can foster innovation.

While the implementation of innovative technologies can be accelerated with the right government-led incentives like subsidies, tax benefits, availability of resources and information, the removal of barriers will be equally if not more effective: less strict regulations or reduced financial risk. Risk is one of the main barriers to innovation. Organizations can control risk by researching innovative technologies to reduce the number of unknowns about them, establishing quality control measures to reduce product deficiencies and training staff to increase their competencies.

Finally, it should be noted that unless social, economic and environmental criteria are all addressed, there is no stability in innovating in the housing process. The ultimate aim of the industry is to produce housing, which provides greater comfort and improved energy efficiency with a higher level of amenity and aesthetics. It is also safe and more secure, using advanced systems and stronger construction techniques. In addition it is healthier through the use of better ventilation techniques and materials, which are more sensitive to the environment and make use of recycled materials and resource-efficient materials, and which provide an improved quality of life for the inhabitants.

REFERENCES

Department for Environment, Food and Rural Affairs (2005) *Sustainable Development Action Plan*.

Department of Trade and Industry (1998) Rethinking Construction 1998.

Department of Trade and Industry (2001) Decent Homes Programme.

Dodgson, M (1994) *The Handbook of Industrial Innovation*. Aldershot: Elgar.

Dodgson, M, Gann, G and Salter, A (2006) *Think, Play, Do: Technology, Innovation and organization*. Oxford: Oxford University Press.

Freeman A M (1991) Valuing Environmental Resources Under Alternative Management Regimes. *Ecological Economics*, **3**(3), 247–56.

Foxall, G (1984) *Corporate Innovation: Marketing and Strategy*. London: Croom Helm.

Gann, D (1996) Construction as a manufacturing process? Similarities and differences between industrialized housing and car production in Japan. *Construction Management and Economics*, **14**(5), 437–50.

Housing Corporation (2005–2008) *Research & Innovation Strategy*.

Kaluarachchi, Y and Jones, K (2007) Monitoring of a Strategic Partnering Process. *Construction Management and Economics,* under review.

Koebel, T (1999) Sustaining Sustainability: Innovation in Housing and the Built Environment. *Journal of Urban Technology,* **6**(3), 75–94.

Latham, Sir M (1994) *Constructing the Team*. London: HMSO.

National Research Council of Canada (2002) *Innovation in the Housing Industry*. Holmen Enterprises Ltd; Institute for Research in Construction.

Kragh, M (2001) *Monitoring of Advanced Facades and Environmental Systems,* PhD Paper presented at The whole-life performance of facades, University of Bath, CWCT, 18/19 April, Bath.

Livesey, F (1983) *Economics for Business Decisions*. Plymouth, Macdonald & Evans.

Seaden, G (November 2005) Defining Construction Innovation, Editorial, *CIB Info Bulletins*. Available online: http://cibworld.xs4all.nl/dl/ib/0004/Pages/Edit.html

Seaden, G, Guolla, M, Doutriaux, J and Nash, J (2003) Strategic decisions and innovation in construction firms. *Construction Management and Economics*, **21**, 603–12.

Serpell, A and Ocaranza, R (2001) Technology innovation in the Chilean Construction industry: s diagnosis of the current situation. *In: Proceedings of the First International Conference on Innovation in Architecture, Engineering and Construction*, Loughborough University, July.

Stern Review (2006) *The Economics of Climate Change*.

Sustainable Homes (2003), Refurbishment Case Studies, Green Street. Available online: http://www.greenstreet.org.uk/

Wigginton M and Harris, J (2002) *Intelligent Skins*. Butterworth-Heinman.

Winch, G (1998) Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research & Information*, **26**(4), 268–79.

A CONGESTION CHARGE FOR DUBLIN

Martin Rogers,[1] Cathal Eagney and Eamonn Maguire

Department of Civil and Structural Engineering, Dublin Institute of Technology, Dublin 1, Ireland

As Dublin becomes more congested, the option of imposing a charge for access to central Dublin at peak times has become a realistic one. This paper outlines, in brief, the history of Dublin transportation planning that has led to this point, lists the alternative number of demand management tools which potentially could be used to limit demand for private car travel to the city centre with the implementation of a congestion charge being an option which would be particularly applicable to Dublin city. The paper details other capital cities where such a charge has been implemented,, indicating in general terms the reasons for the charge and its level of effectiveness in reducing congestion. Estimates of the willingness of road users in Dublin to pay such a charge are put forward. The Dublin Transportation Office's Saturn Model is used to quantify the effect of different congestion charges on car usage into Dublin city centre at peak times. Effective implementation of such a measure is only seen as taking place within the context of improved public transport services within central Dublin.

Keywords: congestion, economics, transportation.

INTRODUCTION

Dublin is now a car city. In the centre of the Dublin City area, household car ownership is 58% and in South Dublin household car ownership is 84% with 41% having at least two cars. Dubliners use their cars to travel to work, to shop, or for leisure purposes. For most people, normal life without a car would be impossible. Dublin is car dependent.

Over-dependency on the car as a mode of travel leads inevitably to traffic congestion. Traffic congestion increases business costs, as moving people and goods around the city takes more time, commuters complain as traffic jams multiply, commuting distances and times grow longer. In addition, it is detrimental to the environment.

Previously in Dublin, transport planning was seen to primarily involve the implementation of the 'predict and supply' model, with the solution to congestion seen to involve the construction of yet more roads. The role of the transport planner was, primarily, to calculate the future levels of car ownership and to ensure that roads are built as quickly as possible to facilitate the classical predict and supply behaviour. However in the context of modern transport planning, this mindset is no longer acceptable. It has been proven that the construction of more roads merely leads to more cars and ultimately more traffic jams on Dublin roads. It has therefore become necessary to consider other measures aimed at reducing congestion in Ireland's capital city, including travel demand management measures.

[1] martin.rogers@dit.ie

TRAVEL DEMAND MEASUREMENT MEASURES

Travel demand measures are primarily demand rather than supply oriented. It is a process which attempts to manage people's travel as opposed to attempting to provide more capacity on the travel network.

Travel demand management therefore involves the putting in place of projects/measures which seek to alter the pattern of travel demand. Booz Allen Hamilton (2004) identified the following ways in which this could be achieved:

- Reduce vehicle use: bring about a reduction in car travel at peak times.
- Increase use of alternative modes of transport: introduce measures to encourage an increase in public transport usage.
- Increase vehicle occupancy: bring about a decrease in single occupancy car trips and encourage multiple-occupancy.
- Reduce trips: bring about a reduction in the need to travel.
- Reduce trip length: plan for the provision of places of employment and shopping outlets in close proximity to residential areas.
- Alter times of travel: encourage travel at off-peak times to lessen congestion.
- Propose alternative destinations for trip makers: encourage trips to destinations that are closer to their origin, along less congested routes.

In the context of Dublin, of the above list of potential measures, the first two were seen as being particularly applicable to the city, i.e. the putting in place of measures to discourage travel at peak times by private car, hand-in-hand with the implementation of infrastructure proposals and associated measures to deliver greater modal share for public transport.

TRANSPORT PLANNING IN DUBLIN

The two most important documents produced by Dublin transport planning authorities in recent years were:

- The Dublin Transport Initiative (DTI) Final Report (1995);
- *A platform for change 2000–2016* (2001).

The DTI Final Report recommended an integrated transportation strategy for the Greater Dublin Area (GDA) for the period up to 2011. The Government of Ireland decided that the DTI strategy should provide the planning framework for the future development of the transport network for the GDA.

The DTI strategy concentrated on public transport enhancement, with extensions to the heavy rail system running along the eastern coast recommended, together with three new light rail lines and the establishment of bus corridors giving priority to the bus system. Demand management was tackled mainly through the strategy of ensuring that no free parking should exist within Dublin's central business district, thus effectively increasing the cost of travel for motorists into the city centre. The Dublin Transportation Office (DTO) was set up in 1995 to carry out the strategy as outlined in the DTI Final Report.

The DTO published the document *A platform for change 2000–2016* in 2001 as an update to the original DTI strategy. While some progress had been made in the intervening years in implementing the basic strategy, there had been considerable slippage in the implementation of elements of the strategy, especially with regard to major public transport infrastructure projects, including light rail and bus. Also, there had been unprecedented economic growth since 1995, leading to very large increases in traffic levels, resulting in much greater congestion.

The main factors influencing increases in the demand for travel are economic growth, increases in population, number of households, number of people in work, growth in car ownership and use. All of these factors have increased since 1991, the date of publication of the first interim DTI Report, and are predicted to continue to do so until 2016.

Table 1 illustrates these trends (DTO, 2001).

Table 1: Factors influencing traffic growth

Greater Dublin Area	**1991**	**1996**	**1999**	**2016**
Population (million)	1.35	1.41	1.46	1.75
Households (’000)	402	446	521	675
Employment (’000)	452	549	681	878
Unemployment rate (%)	16	12	6	5
Car ownership (per ’000 population)	247	292	342	480
% growth in GDP since 1991	–	42	79	260

As can be seen from the data in Table 1, car ownership in the GDA is predicted to almost double in the 25 years between 1991 and 2016, with unemployment cut by two-thirds, population growing by 30%, and the number of households increasing by almost 70%.

As a result of this projected growth in the number of households, the population and car ownership, Dublin city faces a rapidly increasing demand for travel up to 2016, the scale of which is illustrated in Table 2.

Table 2: Factors influencing traffic growth

Greater Dublin Area	**1991**	**1996**	**1999**	**2016**
AM peak hour	172	250	283	488
Off peak hour	107	157	179	256

By 2016, therefore, it is predicted that total peak hour trips will increase by 95% on its 1996 level and by more than 180% on its 1991 level.

In order to deal with these projections, the 2001 document indicated a strategy with two independent elements:

1. **Infrastructure and service improvements**: to increase the supply of transport, including a substantial expansion of the public transport network, some strategic road construction and traffic management.
2. **Demand management**: to reduce the growth in travel through the application of land use and other policies while maintaining economic progress, and which is designed to encourage a transfer of trips, especially at peak periods, from the private car to sustainable modes of transport (bus, rail, cycling and walking).

Therefore, unlike the 1995 DTI document, the 2001 strategy makes explicit reference to demand management being a major part of the transportation strategy for Dublin city.

In 2004, Booz Allen Hamilton completed the document *Greater Dublin Area travel demand management study* for the Dublin Transportation Office in order to progress the demand management element of the 2001 DTO strategy.

Booz Allen Hamilton summarized the problems to be tackled by traffic demand management applied to the Greater Dublin Area:

- Consistent dispersion of the population of the past 25 years, resulting in less sustainable settlement patterns for public transport, leading therefore to a high mode share for private car use. As a result, in 2002, 80% of morning peak hour trips made outside the M50 C-ring motorway (located approximately 10km west of the city centre) are by car.
- The modal share of trips to school/work by car is increasing.
- The overall number of trips made to work by car is increasing.
- In 2002, 50% of all people travelling to work in the central Dublin area did so by car.
- In the future, average car speeds are forecast to decline throughout the GDA, indicating increasing levels of congestion.

To address these problems, Booz Allen Hamilton proposed a package of traffic demand management measures which would:

- influence land use planning, leading to more sustainable and less car dependent settlement patterns;
- facilitate drivers wishing to reduce their car usage; and
- strongly discourage unnecessary car usage in certain areas where alternative modes of transport are available.

The preferred package put forward by Booz Allen Hamilton, as well as proposing land use planning measures such as the promotion of the consolidation of population growth in existing built-up areas and the development of land in close proximity to public transport corridors, and travel demand management measures such as the implementation of workplace travel plans, proposes a city centre congestion charge of €10 applicable between 7am and 10am within Dublin’s central business district.

The remainder of this paper assesses the viability of this fiscal measure. First, other cities with a congestion charge in place are examined in order to evaluate how effective such a policy might be. Secondly, the willingness of Dublin’s drivers to pay the charge is assessed on the basis of a survey carried out by the authors. Finally, using the DTO’s transportation model for Dublin, the authors assess the effect of such a congestion charge on the pattern of morning peak car usage.

REVIEW OF CITY CORDON ROAD PRICING SCHEMES

Schemes currently in operation

London

Congestion charging was introduced into central London in February 2003. As of 2006, London is the largest city to have adopted a congestion charge. It was decided to introduce congestion charging because London had suffered traffic congestion levels among the worst of any European capital city, with drivers in central London spent 50% of their time in queues: every weekday morning the equivalent of 25 busy motorway lanes of traffic attempted to enter central London. It was estimated that London was losing approximately £2–4 million (€3–6 million) every week in terms of lost time caused by congestion.

London operates a cordon-based pricing scheme where drivers must pay to enter the central charging zone, i.e. the Central London area. The fee was originally set at £5 (€7.30) but from 4 July 2005 was increased to £8 (€11.70). The hours of operation are 07.00 to 18.00, Monday through to Friday. Payment can only be made in advance or after the trip is complete, with no payment possible at the cordon control points.

The main aims of the scheme are:

- to reduce congestion in the London area;
- to make radical improvements to the bus services by using revenue collected from tolls to fund improvements to public transport;
- to improve journey time reliability for car users;
- to make the distribution of goods and services more efficient;
- to improve the air quality and reduce levels of harmful emissions and particulates.

The main benefits of the scheme are:

- the scheme generates net revenues of about £100 million – 80% of which is spent on improving bus services within London;
- congestion inside the charging zone reduced by 30%;
- 30% reduction in number of cars and 65 000 fewer car movements;
- 20% increase in movements by buses, coaches and taxis;
- increase of 29 000 bus passengers entering the zone during morning peak.

Bus reliability and journey times improved – the additional time passengers wait at bus stops caused by service delays or missing buses improved by 20% across all of London and by 30% in and around the charging zone.

Rome
Again, this is a cordon-based pricing scheme where drivers must pay to enter the central charging zone, the historical centre of Rome. It was introduces in 1998, the main aim being to reduce traffic in the central area of Rome. Access to the area is free to residents. Other vehicle users purchase a special annual permit which allows them to drive through any of the access gates to the historical centre. Hours of operation are 06.30–18.00 Monday through to Saturday and as of October 2006 restrictions in the very central core will also be applied between 23.00 and 03.00 on Fridays and Saturdays. Plans are underway to expand the current city centre charging zone to the S. Lorenzo and Trastevere districts of Rome with a similar charging scheme being introduced.

The main benefits of the scheme are:

- decrease in traffic of 20% during hours of operation;

- annual payments for permits are in the region of €10 million.

Bergen
This is again a cordon-based pricing scheme where drivers must pay to enter the central charging zone. Introduced in 1986, its main aims are:

- to collect funds for road investments, with some contribution made to public transport;
- to reduce number of vehicles on most congested roads in morning and afternoon rush hours, by 10–15%;
- to improve journey times for cars and buses in the inner part of the city;
- to reduce air pollution.

Only ingoing traffic is charged for entering the cordon (city centre). The hours of operation are weekdays, 06.00 to 22.00. The scheme is currently in operation with a charge of 15NOK (€1.85) for traffic weighing up to 3500kg (cars) and 30NOK (€3.68) for traffic weighing over 3500kg (trucks).

The main benefits of the scheme are seen as significant revenue generation, along with a 7% decrease in traffic volumes during the day.

Oslo
This is again a cordon-based pricing scheme where drivers must pay to enter the central charging zone. Introduced in 1990, its main aim is to collect funds for road investments, with some contribution made to public transport.

The scheme operates on the basis that only ingoing traffic is charged for entering the cordon (city centre). Hours of operation are 24 hours a day 7 days a week. The scheme is currently in operation with a charge of 20NOK (€2.45) for traffic weighing up to 3500kg (cars) and 40NOK (€4.90) for traffic weighing over 3500kg (trucks).

The scheme is seen as generating substantial revenue, in tandem with reduction in queuing and delays and better road safety. Initial public opinion was not in favour; now 70% back the scheme. Furthermore, surveys would seem to indicate that initial negativity towards the scheme tends to dissipate once the benefits of its operation are felt by the residents. But would this also be the case with Dublin.

Durham
Durham has a cordon-based system where Durham’s peninsula can be accessed by a single road only. The charge is payable on exit from the area. Introduced in 2002, the main aims of the scheme are as follows:

- improvement in pedestrian safety;
- improvement in access for the disabled;
- enhancement of a World Heritage site;
- sustaining the viability of the city centre.

The scheme operates as follows. Traffic leaving the central area during the hours 10.00–16.00, Monday through to Saturday is charged. There is currently a charge of £2.00 (€2.95) to leave the cordon area during the hours of operation.

The revenues generated are used to support a frequent bus service to and from the charging area. There is a reduction of 85% in vehicular traffic with a 10% increase in pedestrian activity, with 83% of businesses having altered their servicing arrangements following the introduction of the charge.

Comment on effectiveness of schemes in place in other European cities
The majority of the above schemes generate substantial revenues in tandem with bringing about major reductions in congestion within the city centre. Surveys seem to indicate that initial resistance from the public seems to dissipate once the benefits of the scheme are felt by the city's inhabitants.

THE FINANCIAL BENEFITS OF A CONGESTION CHARGE WITHIN DUBLIN CITY

The costs of implementing the congestion charge
Table 3 details the costs associated with the introduction of congestion charging to Dublin as detailed by Booz Allen Hamilton (2004).

Table 3: Costs associated with congestion charging

Capital costs	**€ million**
System set-up – over three years	50
Complementary traffic management measures – over two years	44
Education/awareness programme – once off	5
Recurring costs	
Scheme administration – annual	5
Scheme operations – annual	60–120

They are seen to comprise a set-up charge of three years of €50 million, with the implementation of complementary traffic management measures costing €44 million and a once-off costing of €5 million for an education/awareness programme. Annual costs to cover the administration and operation of the scheme come to between €65 and €125 million per year.

The revenues projected from the introduction of the congestion charge
On the basis of a €10 congestion charge, levied between 7am and 10am, with a consequent reduction of 31% in vehicle movements within the cordon area assumed, the revenues estimated by Booz Allen Hamilton are detailed in Table 4.

Table 4: Annual revenues associated with congestion charging

Annual revenues	**€ million**
Congestion charge fees paid by vehicles crossing cordon	144
Congestion charge paid by residents within cordon	94

They are seen to comprise annual revenue of €144 million from the congestion charge payable by those crossing the cordon to enter the central business district, plus annual revenue of €94 million from the fees paid by residents living within the central business district. Thus total revenues from the congestion charge are predicted to be €238 million per year, a minimum of almost twice the annualized equivalent of the predicted initial set-up and ongoing operating costs.

If, as in the case of the London congestion charge, certain groups of drivers were to be exempted from the charge or have the charge heavily discounted, this could reduce revenue by up to one-third. However, even under this scenario, the financial case for the imposition of such a charge remains strong.

WILLINGNESS OF DUBLIN MOTORISTS TO PAY CONGESTION CHARGE

Introduction

While the financial argument for the imposition of the congestion charge would appear strong, it is important to gauge the willingness of Dublin motorists to pay any such charge imposed on them.

To this end, the authors undertook a survey of 100 motorists entering the Dublin central business district. Carried out during the period October to November 2006, the results point to the general opinion of car users who may be subjected to the charge.

The survey findings

The main questions the survey programme sought to answer were:

- whether people would be willing to pay a charge to cross the cordon at the entrance to Dublin's central business district if it meant less congestion on the roads; and if so
- what level of charge would they be willing to pay.

The survey also wanted to establish the number of trips those surveyed were making into the city every week and for what purpose.

Results indicated a majority of commuters driving into the CBD five days a week (57%) with the purpose of the trip for most drivers being the journey to work (67%).

When asked 'How much would you be willing to pay to drive into the Central Dublin Business District (City Centre) if a congestion charge were imposed between the hours of 7.00am and 10.00am?', the responses were as shown in Table 5.

Table 5: Willingness of Dublin motorists to pay congestion charge

Charge (€)	Willingness to pay charge (%)
0	100
1.5	90
2.5	83
5	50
7.5	20
10	10
15	0

Table 5 indicates that 50% of those commuting into Dublin by private car would be willing to pay a congestion charge of €5, with 20% willing to pay €7.50 and 10% willing to pay the €10 charge proposed by Booz Allen Hamilton.

While revealed preference surveys such as this have historically tended to underestimate the willingness of respondents to pay for the good being surveyed, the results do confirm a reasonable level of willingness to accept the introduction of such a charge. Given that motorists travelling into the city centre of Dublin are willing to pay up to €2.50 per hour for on-street parking, it would be reasonable to assume that the majority of the car-based commuters would be willing to pay a charge in the region of €7.50 to €10 for entering the city centre cordon at peak times.

In addition, the newly opened port tunnel in Dublin, bringing vehicles from the motorway C-ring on the western outskirts of Dublin into the port area in the city centre, is free for trucks but charges cars €12 during peak times and €3/€6 during off-peak periods. Latest figures indicate that 22% of the users over the entire 24-hour period are private car-based.

To conclude, based on data from the willingness-to-pay survey, it would be reasonable to assume that a charge in the region of €7.50 to €10 would be broadly acceptable to a reasonable proportion of car-based commuters, with data from the Port Tunnel indicating motorists willing to pay a toll in excess of this charge.

Given that a level of acceptability exists among car-based commuters with regard to the imposition of such a charge, what needs to be examined next is the level of congestion reduction that would result from the imposition of such charges in Dublin city.

RESULTS FROM DTO TRANSPORTATION MODEL

With the cooperation of senior personnel in the DTO, the authors utilized the DTO Saturn transportation model for Dublin to assess the effect of different levels of congestion charging on the modal share within the central business district of the city.

The model was run for three congestion charge levels, €0, €7.50 and €15. The assessment was completed on the basis of the existing transportation network within the city. No proposed road or public transport improvements were factored into the analysis. The €0 charge thus represents an analysis of the baseline/existing situation.

Table 6 indicates the changes in modal share for private cars entering the cordon at the entrance to the central business district between the hours of 7am and 10am weekdays for the three proposed charges. Table 7 indicates the changes in modal share for private cars within the cordon area between the hours of 7am and 10am weekdays for the three proposed charges.

Table 6: Effect of congestion charges on no. of cars attracted into city centre area

Modal share and total no. of car-based trips attracted to city centre area	**Modal share (%)**	**Total no. of vehicles**	**% Reduction in no. of vehicles**
Charge		0700 to 1000 weekdays	
€0	54	84110	–
€7.50	45	68299	19
€10	32	48824	42

Table 7: Effect of congestion charges on no. of cars attracted into city centre area

Modal share and total no. of car-based trips within city centre area	**Modal share (%)**	**Total no. of vehicles**	**% reduction in no. of vehicles**
Charge		0700 to 1000 weekdays	
€0	53	97606	–
€7.50	45	82011	16

€10	35	63203	35

Thus, a charge of €7.50 will result in a reduction of 19% in the number of cars entering the CBD and 16% in the total number of car movements within the area, while a charge of €15 will result in a reduction of 42% in the number of cars entering the CBD and 35% in the total number of car movements within the area.

By interpolating between the results obtained for the €7.50 and €15 congestion charges, it could be reasonably inferred that a charge of €10, as put forward by Booz Allen Hamilton (2004) will bring about a reduction in car usage levels of approximately 30%, along the lines of the reductions obtained in London.

CONCLUSIONS

In recent years, transport planners in Dublin have begun to consider the feasibility of introducing a congestion charge in the city's central business district. Experience in other capital cities points to the effectiveness of such schemes in reducing car usage at peak weekday times. Use of the DTO's transportation model for Dublin indicates that the imposition of a €10 charge at peak times will lead to a reduction of approximately 30% in car usage within the city centre. While surveys of Dublin motorists indicate a limited willingness to pay this level of charge, such surveys would tend to be overly conservative in their predictions. This proposition is supported by data from the newly opened Dublin Port Tunnel, where car-based commuters are willing to pay a charge of €12 at peak times. Furthermore, as the public transport infrastructure within the Greater Dublin Area improves, particularly with the completion of the proposed Metro system, resistance to the imposition of a congestion charge will diminish as commuters are given viable and efficient alternative modes of travel into the city centre.

ACKNOWLEDGEMENTS

The help and cooperation of the Dublin Transportation Office in the production of results for this paper is greatly appreciated by the authors.

REFERENCES

Booz Allen Hamilton (2004). *Greater Dublin Area travel demand management study*. Dublin: Dublin Transportation Office.

DTO (2001) *A platform for change 2001–2016*. Dublin: DTO.

Dublin Transportation Initiative, Steer Davies Gleave, McHugh Consultants (1995) *Dublin Transport Initiative: final report.* Dublin: Stationery Office.

RISK ASSESSMENT IN CONSTRUCTION COST ESTIMATION OF A MOTORWAY PROJECT

Giray Kumas[1] and S. Ergonul[2]

[1]*Enka Insaat ve Sanayi A.S, Moscow Office, 115054, 1st Shluzoviy Pereulok, 2/7 Paveletskaya, Moscow, Russia*
[2]*Department of Architecture, Mimar Sinan Fine Arts University, Findikli, 34427, Istanbul, Turkey*

Construction projects face substantial and unique risk factors at every stage. These factors threaten the project targets unless the uncertainty is moved away from the project. Risk management is one of the most effective systems in order to optimize performance and minimize the risks involved in a project. This process has to be realized and considered in every stage of a project. This study presents potential risks that cause an increase in the total construction cost and analyses how construction risks are assessed in a motorway project. Construction risks are considered from the contractor's point of view. First, real forecasts of the motorway project provided by the contractor are analysed in order to define contractor's risk policy. Then, the existing risks are assessed by a probabilistic, Monte Carlo simulation method using crystal ball software. The results of the simulation method are compared with the results of the actual situation. The results show that simulation method helps the contractors to manage the costs with high risk.

Keywords: cost, estimating, risk, simulation.

INTRODUCTION

Construction projects are characterized as very complex projects, where uncertainty comes from various sources (Miller and Lessard 2001). These projects are characterized by continuous decision making due to numerous sources of risk and uncertainty, many of which are not under the direct control of project participants (Baloi and Price 2003). Risks associated with construction projects are potentially serious and have high financial and social impacts (security/safety, reputation/image, quality of life, etc.) on major parties involved in the project, such as the owners, consultants, contractors, subcontractors, suppliers, insurers or financiers (Taş 1994). Construction projects have a bad reputation of failing to meet the deadlines and cost targets (Mills 2001). That is why identifying risk sources is extremely important, since it is not necessarily possible to identify every single risk.

There are a great number of risks associated with construction. Cohen and Palmer (2004) identified risk trends in construction projects. They found that typically, risks are determined at the very early phases of the project (feasibility and planning) while the impacts are not experienced until the construction and production start-up phases. They list typical sources for risks in construction projects as technical, social, construction, economic, legal, financial, natural, commercial, logistical and political.

[1] giraykumas@yahoo.com

The effect of any of these risks eventually can be expressed in terms of monetary loss, property damage, personal injury or a combination of these.

Odeh and Battaineh (2002) studied the most typical reasons for construction delays in Far East construction projects. They found seven significant causes of delays: owner interference, inadequate contractor experience, financing and payments, labour productivity, slow decision making, improper planning and subcontractors. According to Mills (2001) three of the most important risks in construction projects are weather, productivity of labour and plant and quality of material. These areas are not easily controllable by a contractor before the project execution.

In recent years, thanks to the increase in technical complexity and the need for economic, environmental, legal and political viability present in modern society, concern over risk has been growing. This concern generates a need for effective risk management. The risk management process should be implemented at the early project phases, when there is still a possibility for fundamental changes (Chapman 1997). The project should be carefully analysed as to which kind of methods to use at which project phases and a process needs to be customized according to all project characteristics.

This study aims to analyse construction project risks which affect the total cost and to examine how risks are taken into account for a motorway project. Construction risks in cost estimation are considered from the contractor's point of view. Risks of the motorway project are assessed by practical and probabilistic approach.

RISK MANAGEMENT IN CONSTRUCTION PROJECTS

Ababneh (2000) expresses risk management as the science of optimizing performance and minimizing the risks involved in successfully completing a project. However, in order to optimize, it is also necessary to appreciate the nature and the consequences of the risk involved. A risk management process should therefore encompass all these functions.

The Project Management Body of Knowledge (PMBOK) (PMI 2000) details risk management processes as risk identification, risk analysis, risk response planning and risk monitoring and control. Risk identification is stressed by many researchers (Chapman 1997; Turner 1999; Chapman 2001). Identification of the risks should be the initial step in all projects. After risks have been identified, the next step is to evaluate them. This means establishing how serious the risks are, in terms of both their potential severity and extent, and their likelihood of occurrence or judgement measures. Risk response is defined by PMBOK (PMI 2000) as the process of developing options and determining actions to enhance opportunities and reduce threats to the project objectives. Literature (Turner 1999; PMI 2000) suggests that there are generally four response types to cope with risk:

- Avoid: change in project plans in a way that an identified risk is no longer relevant.
- Transfer: transfer risks to other parties by contracts or insurances.
- Mitigate: find ways to reduce the probability and/or impact of risk.
- Accept: take a conscious risk and deal with negative consequences as they occur, but take no action beforehand.

Risks in construction projects are a significant element of the total project costs and thus their allocation has a major effect on project budget (Zaghloul and Hartman 2003). Construction organizations operate within an environment and not a vacuum. They are inevitably influenced by and constantly interacting with their environment. Hence, construction projects are open systems, rather than closed systems, which adds to the variability and riskiness of the project (Baloi and Price 2003). The risk management process has to be adjusted to the cooperative environment, where multiple actors manage risks together in construction projects, but unfortunately this has not yet happened. Risk management in the construction industry still relies heavily on contracts, and the industry has the bad reputation of becoming involved in numerous disputes and claims. According to various studies (Baloi and Price 2001; Floricel and Miller 2001), contractual structures are the main sources of the lack of flexibility and they have a significant negative effect on the actor relationships. Apart from contracts, studies show that construction risks are mainly handled with experience, assumption and human judgement (Baloi and Price 2003).

CASE STUDY

In order to analyse how risks are considered in cost estimation, a case study is carried out. A motorway project which was executed in Croatia in 2002 is selected for the case study. The contractor of the project is a joint venture (JV). The names of the partners of the JV are not stated in this study to respect confidentiality. The type of contract between the JV and the employer is unit price and the scope of the project is a 220km motorway with viaducts, underpasses, overpasses and with a cost of US$950 million. In the case study, first the contractor’s risk policy is explained to analyse the actual situation. Then, a probabilistic approach to cost estimation of the motorway project is presented.

The contractor’s approach to risk

In the project cost estimation, forecasts provide a framework to analyse the present situation and also assist analysis of the short-term prospects. Forecast is a kind of calculation which is done periodically during the execution of the project. The period of the forecast changes depending on the contractor’s policy (once or twice per year).

In this study, real forecasts of the motorway project are taken into account to define the contractor’s risk policy in actual situations. The first forecast of the project is done immediately after signing the construction contract and six months later updated by Forecast 2 which is later on updated by Forecast 3. This study covers the second and third forecasts of the project because they are the only forecasts provided by the JV.

Table 1 shows the cost values of forecasts of the JV. Total cost consists of direct costs, indirect costs, provisional sum and management reserve. All the costs of the contractor are calculated in a forecast and updated by next forecasts throughout the project. Risks, which are identified throughout the project, are also analysed in this way, and their results are included in the forecast. As a result of each forecast, the contractor foresees remaining turnover, financial expenses and probable risks. Therefore, the contractor can decide which precautions need to be taken for the following periods. For example, intended cash flow can suffer many changes during the project. Financial risks can be assessed easily owing to forecasts for subsequent periods, and cash flow can be rearranged (Galipoğulları 2001).

Management reserve in the forecasts refers to potential risks considered in cost estimation. This reserve is a measure for accepted risks. In other words, it is a budget assigned by the JV for the risks and used in order to protect the cash flow against any adverse impacts of these risks.

A share is assigned for unforeseen risks in management reserve, and such share is called ‘Remaining contingency’ which is about 5% of direct costs depending on the JV’s experience. In the contract there is no clause for escalation; therefore, depending on the historical data the JV includes the risks of inflation and exchange rate in management reserve. ‘Section 1 borrow settlement’ is an existing dispute between the JV and employer. This dispute might be settled adversely for the JV, and the monetary size of its impact to cost is added to the reserve. For confidentiality reasons, detailed information regarding ‘Financial costs for $150M’ and ‘Potential unrealized value’ is not given by the JV. They are two foreseen risk items, and have been accounted for in management reserve. The JV realizes that the local wage rates are likely to increase more than the escalation. Other contingencies cover wage rates as well as quarries, land leases, transportation and so on.

Table 1: Cost forecasts of the motorway project, US$ million

Costs	FC 2	FC 3	FC3-FC2
Direct costs			
Labour	32.5	32.4	–0.1
Material	41.6	43.5	1.9
Subcontracts	126.4	147.9	21.5
Manufacturing	66.1	50.2	–15.9
Equipment	91.6	87.1	–4.5
Provisional sum	16.6	18.5	1.9
Indirect cost			
Non-manual cost (health insurance, taxes, etc.)	33.1	37.1	4.0
Camps and plant set-ups/Demo	28.0	31.7	3.7
Maintenance, transportation, meals, etc.	51.8	54.9	3.1
Equipment for maintenance	10.5	7.4	–3.1
Communications, office supplies, other office	13.3	12.6	–0.7
Customs, taxes, insurances, bonds	22.5	22.8	0.3
Subtotal cost	534.0	546.1	12.1
Management reserve			
Remaining contingency @ 5.0%	19.5	17.0	–2.5
Escalation	31.7	21.9	–9.8
Potential unrealized value	9.5	0.0	–9.5
Financial costs for $150M	1.5	0.0	–1.5
Section 1 borrow settlement	1.5	0.0	–1.5
Other contingencies	0.0	37.5	37.5
Total management reserve	63.7	76.4	12.7
Total cost	597.7	622.5	24.8

As explained above, some of the risks are included in management reserve. However, Table 2 presents the allocation of the other risks. As seen in Table 2, the JV chooses risk transfer for risks of ‘Accidents’, ‘Acts of God or government’, ‘Materials and equipment’ and ‘Safety at site’. All these risks are covered in insurance. Insurance may be the choice of the JV or the local legislations or the contract may require it for some risks. The JV accepts the risk of ‘Choice of subcontractor’, ‘Inflation’ and ‘Payment delays’ and assigns reserves for them in management reserve. There are also some risks that are allocated elsewhere but not provided by the JV such as ‘Poor site investigations’, ‘Defective work’, ‘Weather conditions’ and ‘Management incompetence’.

Probabilistic approach to risk

Estimates are probabilistic assessments, therefore costs may actually be higher or lower than estimated even by seasoned professional estimators. The reasons are often causes that are outside the control of the project manager, but may also be endemic to the estimating process, the project strategy or the corporate culture within the project contractor (Hulett 1999).

Table 2: Most probable risks undertaken by the JV

Type of risk	Type of risk response	Policy of the JV
Currency risk	Risk acceptance	Management reserve (escalation)
Payment delays	Risk acceptance	Contract (late payment interest clause)
Inflation	Risk acceptance	Management reserve (escalation)
Accidents	Risk transfer	Insurance (liability insurances)
Vague contract conditions	Risk acceptance	Management reserve (other contingencies)
Ambiguous specifications	Risk acceptance	Management reserve (other contingencies)
Defective drawings	Risk acceptance	Management reserve (other contingencies)
Acts of God or government	Risk transfer	Insurance (CAR & property insurance)
Choice of subcontractor	Risk acceptance	Management reserve (other contingencies)
Quantity variations	Risk acceptance	Management reserve (potential time ext.)
Materials and equipment	Risk transfer	Insurance (property insurance)
Labour problems & union strife	Risk acceptance	Management reserve (other contingencies)
Delays in the work	Risk acceptance	Management reserve (potential time ext.)
Safety at site	Risk transfer	Insurance (miscellaneous Insurance)

In the probabilistic approach Monte Carlo simulation is accepted as the probabilistic method and crystal ball is used to simulate the construction cost of the motorway project. There are three important issues in Monte Carlo simulation. The first one is to specify reasonable statistical distribution for any cost component subject to variation. The second issue is that cost correlations between individual components should be known and accounted for. The crystal ball software uses the Iman and Conover method for generating correlated random numbers. The third issue is the number of simulation runs.

Table 3 presents cost components, which are accepted as random variables in Monte Carlo simulation as they are responsive to any alterations in design and construction. Each cost component has its minimum, mean (most likely) and maximum values depending on Forecast 2 and Forecast 3. In the analysis of cost values of both forecasts it is seen that assigning a standard deviation to cost components is not possible because the minimum and maximum ranges are not symmetrical. Forecasts provide a greater likelihood for overruns than for underruns. The triangular distribution describes a situation where minimum and maximum values are known (Moran 1996). Therefore, triangular distribution with minimum and maximum values is satisfactorily assigned to cost components. In the evaluation of Forecast 2 and Forecast 3, it is assumed that a value which is 5% less than mean cost and a value which is 25% more than mean cost satisfactorily represent the minimum and maximum cost values respectively (Giray 2005).

In all simulation experiments conducted in this study, the results remained virtually unchanged after 3.000 runs. Therefore, running the model 5.000 times will provide a satisfactory distribution for the construction cost estimation.

Figure 1 shows the construction cost distribution for the motorway project. Table 4 summarizes the statistical results of the Monte Carlo simulation. The mean is US$582.2 million with a standard deviation of US$12.58 million.

Table 3: Cost components and their distribution, US$ million

Cost component	Minimum cost	Most likely cost	Maximum cost	Distribution
Labour	30.8	32.4	40.5	TRIANGLE DISTRIBUTION
Material	41.3	43.5	54.4	
Subcontracts	140.5	147.9	184.9	
Manufacturing	47.7	50.2	62.8	
Equipment	82.7	87.1	108.9	
Provisional sum	17.6	18.5	23.1	
Non-manual (health insurance, taxes, etc.)	35.2	37.1	46.4	
Camps and plant set-ups	30.1	31.7	39.6	
Maintenance, transportation, meals, etc.	52.2	54.9	68.6	
Equipment for maintenance	7.0	7.4	9.3	
Communications, office supplies, other office	12.0	12.6	15.8	
Customs, taxes, insurances, bonds	21.7	22.8	28.5	
Total estimated cost	518.8	546.1	766.5	

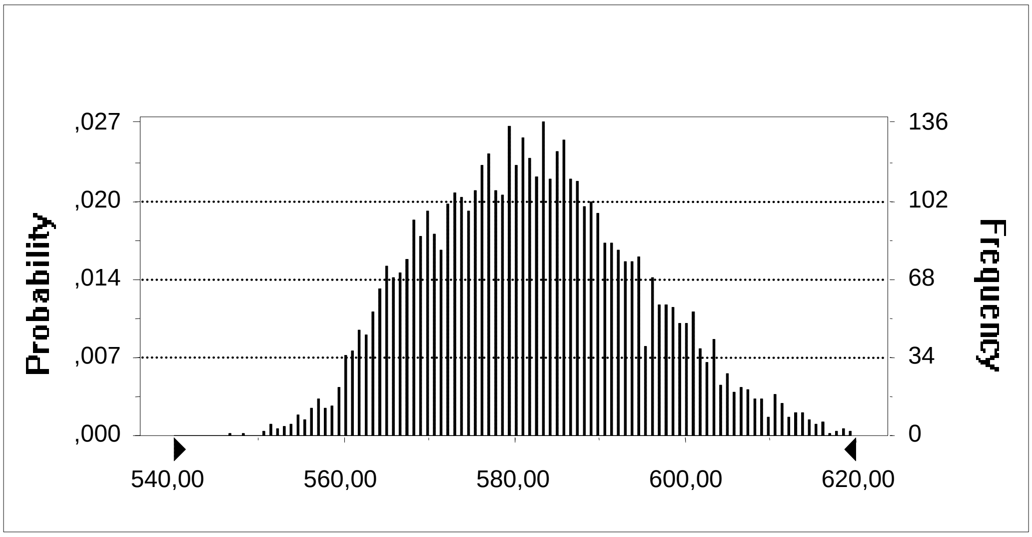


Figure 1: Probability distribution of the project cost, US$ million

Table 5 shows the probabilities of the construction cost that occurs. The probability of having a construction cost that is less than US$581.72 million is 50%. In order to cover existing risks, total construction cost is to be US$624.48 million. That means that almost US$77.58 million should be set aside in addition to the construction cost with no risk assigned.

Table 4: Simulation results for project cost estimation, US$ million

Statistics	Value
Trials	5.000
Mean	582.20
Median	581.72

Standard deviation	12.58
Variance	158.19
Coeff. of Variability	0.02
Range minimum	546.90
Range maximum	624.48

Table 5: Probability of the project cost

Percentile	Estimated cost of the project, US$ million
0%	546.90
10%	565.98
20%	570.72
30%	574.86
40%	578.44
50%	581.72
60%	584.97
70%	588.49
80%	592.89
90%	599.24
100%	624.48

Monte Carlo simulation enables us to identify the high-risk cost elements and rank them by their contribution to risk in the project (Hulett 1999). Sensitivity analysis of Monte Carlo simulation shows that construction cost is more sensitive to the cost components of subcontracts, equipment, maintenance and manufacturing as average 74%, 40%, 26% and 22% respectively. It provides less sensitivity to the equipment for maintenance and provisional sum.

Table 6 compares the simulated costs with actual recorded costs on the project. In the comparison of total project cost without any risk consideration and with possible risk consideration, the simulated results provide a reserve of $77.58 million while actual recorded reserve is $764 million. The results show that the probabilistic approach provides reliable results for the construction cost estimation.

Table 6: Comparison of simulation results with the actual recorded results, US$ million

Total project cost	Actual	Simulation
Without considering any risk	546.1	546.90
With considering risks	622.5	624.48

CONCLUSIONS

The construction industry is one of the most risky sectors owing to its dynamic and unique characteristics. A highly competitive environment makes contractors assume many risks on their own. These risks may affect contractors in many ways and cause high financial and social impacts.

In this study possible construction project risks and their allocation are discussed. Construction contracts may help to mitigate project risks but there are many risk factors that cannot be referred to construction contracts and usually the allocation of risks with any other method presents additional costs. The correct allocation method has to be defined and established successfully in order to save the project finance.

Risk assessment of a motorway project is analysed by actual and probabilistic approach. A dynamic risk management process is established in practice. Transferred risks are covered by insurance. However, for accepted risks identified during the project, reserves are assigned in order to save the project finance. In the comparison of actual results with simulation results, Monte Carlo simulation presents reliable results if the maximum and minimum values of the simulation are estimated accurately.

REFERENCES

Ababneh, W A (2000) *An integral approach of construction risk management and evaluation*, Unpublished MSc Thesis, Istanbul Technical University.

Baloi, D and Price, A D F (2001) Evaluation of global risk factors affecting cost performance in Mozambique. Paper presented at the COBRA, Cutting Edge and Roots Conference, available at www.rics-foundation.org.

Baloi, D and Price, A D F (2003) Modelling global risk factors affecting construction cost performance. *International Journal of Project Management*, **21**(4), 261–9.

Chapman, C (1997) Project risk analysis and management: PRAM the generic process. *International Journal of Project Management*, **15**(5), 273–81.

Chapman, R J (2001) The controlling influences on effective risk identification and assessment for construction design management. *International Journal of Project Management*, **19**(3), 147–60.

Cohen, M W and Palmer, G R (2004) Project risk identification and management, AACE International Transactions.

Floricel, S and Miller, R (2001) Strategizing for anticipated risks and turbulence in largescale engineering projects. *International Journal of Project Management*, **19**(8), 445–55.

Galipoğulları, N (2001) Şantiye yöneticileri için inşaat yönetimi, Istanbul.

Giray, K (2005) *Risk analysis of construction projects: a case study on a motorway project*, Unpublished MSc Thesis, Mimar Sinan Fine Arts University, Istanbul.

Hulett, D T (1999) *Project cost risk analysis using crystal ball*, available at www.projectrisk.com.

Miller, R and Lessard, D (2001) Understanding and managing risks in large engineering projects. *International Journal of Project Management*, **19**(8), 437–43.

Mills, A (2001) A systematic approach to risk management for construction. *Structural Survey*, **19**(5), 245–52.

Moran, S R (1996) Observations on AF/SMC proposal cost-risk evaluation techniques. Discussion Paper, Advanced Programs and Technology, Lockheed Martin Missiles & Space.

Odeh, A M and Battaineh, H T (2002) Causes of construction delay: traditional contracts. *International Journal of Project Management*, **20**(1), 67–73.

PMI (2000) *A guide to the project management body of knowledge*. Pennsylvania: Project Management Institute.

Taş, E (1994) *Yüklenici inşaat işletmeleri için proje özelliklerinin ve riskin dikkate alındığı finansal planlama modeli*, Unpublished PhD Thesis, Istanbul Technical University.

Turner, J R (1999) *The handbook of project-based management: improving the processes for achieving strategic objectives*. 2ed. London: McGraw-Hill.

Zaghloul, R and Hartman, F (2003) Construction contracts: the cost of mistrust. *International Journal of Project Management*, **21**(6), 419–24.

USING PROJECT LEARNING TO ENHANCE THE VALUE OF CONSTRUCTION PROJECTS

Hamzah Abdul-Rahman,[1] Mohd Suhaimi Mohd Danuri, Low Wai Wah, Norhanim Zakaria and Faizul Azli Mohd Rahim

Center of Project and Facilities Management (PFM), Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia

Project learning has captured the attention in the construction industry as a means to share and acquire knowledge. Loss of knowledge gained over the years and unavailability of relevant knowledge at the project phases are typical issues in the construction industry. A study was conducted to explore the learning practice of contractors and to determine how project learning can enhance the value of construction projects. The research was focused on pre-construction stage and targeted the larger groups of contractors. Quantitative and qualitative methodologies were employed in the study. Preliminary findings indicated that project level learning is spontaneity and highly individualized, periodic meeting and informal communication are usual modes of learning, and lesson learned is seldom disseminated to project-related parties during the execution of project. Questionnaire survey uncovered that learning in construction is less formalized, and discussion and knowledge sharing among project team are capable to enhance project value. Findings indicated the need to focus on learning process and establishing a practical system to capture knowledge. A model was proposed for continuous project learning to assist organizations in realizing the quest and utilization of project knowledge.

Keywords: construction, knowledge, project learning.

INTRODUCTION

Construction is a project-oriented and knowledge-based industry (Fong and Chu 2006). Each construction project is rich with significant learning opportunities (Eliufoo 2002). Getting the full value from these characteristics of the industry should advance the industry a step forward. Nonetheless, construction industry seems to move backward (Kadefors 1995; Woudhuysen and Abley 2004) and there is a need to offer added value to the customers and the society (Kristiansen *et al*. 2005).

Value is increasing emphasized in today's world (Rowlinson 2005) and construction is not an exception. Value is typically defined as the cost of least expensive way to deliver the desired functional performance (Watson 2005). Improving value ensures quality, reliability, performance, and other critical factors of a project meet or exceed customer's expectations (Dell'Isola 1997). A project is considered value for money to the client if specifications related to time, cost and quality are achieved.

Issues of low quality, delay and cost overruns (Hussein 2003; Abdul-Rahman and Berawi 2002; Abdul-Rahman *et al*. 2006) are still common in the Malaysian construction industry. A survey discovered that lack of knowledge contributes a role in construction project failures (Leong 2006). Another survey found that unavailable

[1] arhamzah@um.edu.my

of relevant knowledge throughout the project phases is the reason behind the lack of constructability (Nima *et al*. 2002). Accordingly, learning within a project relates to project success or failure and may affect the value of the project (Storm and Savelsbergh 2005) as new knowledge is needed constantly to improve the value of future projects.

Project learning emerges as a vital approach in knowledge-based development which concerns with the set of actions used by project teams to create and share knowledge within and across projects (Kotnour 2000). It is an important value driver in construction projects as current post project evaluation is doubted in its ability to capturing and reusing of lessons learned (Kamara *et al*. 2003, 2002). Moreover, construction professionals and policy makers seem to have failed to implement knowledge sharing among projects parties (Hussein 2003; Berawi 2004).

LITERATURE REVIEW

Learning becomes an attentive issue in the construction industry either at the organizational level or at the project level. Methods used in knowledge management (Carrillo 2004; Bresnen *et al*. 2003; Carrillo *et al*. 2004), knowledge transfer (Eliufoo 2002; Brochner *et al*. 2004), knowledge sharing (Fong and Chu 2006), organizational learning (Kululanga *et al*. 1999; Love *et al*. 2003) and project learning (Gieskes and Broeke 2000; Fong and Yip 2006) have been the dominant focus to many researches. These researches provide contribution of knowledge on a list of methods of managing knowledge and learning in the construction industry. However, researchers give less attention on the learning initiative especially in developing nations, like Malaysia. Chan *et al*. (2005: 747) raised a question “whether organizational learning at the construction project level is applicable”. This thought touches the future scope of research to explore whether organizational learning methods can be fully adopted at the construction project.

Some studies looked at the benefits of learning and knowledge initiatives (Puddicombe 2006; Fong and Chu 2006). These researches make a good point of departure in an academic research as less empirical studies, either qualitative or quantitative, focus on the advantages of learning and knowledge initiatives.

Other studies have focused on practical-related problems including to develop learning and knowledge initiative models (Fong 2003; Kamara *et al*. 2003; Robinson *et al*. 2004; Tserng and Lin 2004; Lin *et al*. 2005). Nevertheless, there is scarcity of developed models that looks into the subject of continuous learning. This subject is important as lack of standard work process constitutes a main barrier for the application of knowledge management in the construction (Carrillo *et al*. 2004; Carrillo 2004). This implies the danger of knowledge loss and the need of a standard framework to ensure that learning and knowledge can effectively take place.

RESEARCH AIMS, OBJECTIVES AND SCOPE

Based on issues confronting the construction industry and the previous literatures voids, the study aims to review project learning practices and benefits gained by contractor organizations during pre-construction stage. The objectives include:

1. To identify the current project learning approaches among local contractors and to determine whether organizational learning methods can be fully adopted as construction project learning method.

2. To find out the major elements that can be significantly improved through project learning exercise; and
3. To develop a continuous project learning model.

MODEL DEVELOPMENT

Comparison to some existing developed models

A continuous project learning model is proposed based on three basic principles, namely, knowledge management, continuous collaborative learning and lesson learned. The principal intention of the proposed model is to enhance learning and project knowledge management in the construction projects. In Fong's (2003) study, three knowledge processes of knowledge sharing, knowledge generation and knowledge integration are highlighted and collective project learning is considered as the central to the three knowledge processes. Kamara *et al*. (2003) focused on the live capture and reuse of project knowledge and recommended the use of learning histories, collaborative learning, project extranets and workflow management. Robinson *et al.* (2004) suggested the integration of knowledge management strategy into business case in construction organizations. Tserng and Lin (2004) and Lin *et al*. (2005), on the other hand, addressed the use of knowledge management by contractors in the construction phase. Table 1 shows the focus areas of knowledge management between the proposed model and existing developed models.

Table 1: Comparison of the proposed model to others existing developed models

Knowledge management areas	**Authors**				**The present proposed model**
	Fong (2003)	**Kamara *et al.* (2003)**	**Robinson *et al.* (2004)**	**Tserng and Lin (2004); Lin *et al.* (2005)**	
Knowledge gap	×	×	×	×	✓
Knowledge goal	×	✓	✓	×	✓
Know. identification	×	×	✓	✓	✓
Knowledge creation	✓	✓	✓	✓	✓
Knowledge sharing	✓	✓	✓	✓	✓
Knowledge linkage	×	×	✓	✓	✓
Knowledge filtering	×	✓	×	×	✓
Knowledge storage	×	✓	✓	✓	✓
Knowledge retrieve	×	✓	×	✓	✓
Knowledge dissemination	×	✓	×	×	✓
Knowledge update	×	×	✓	✓	✓

Theoretical perspectives of the developed model

The theoretical perspectives of the developed model are based on the integration of team learning theory (including individual learning reviews, functional learning reviews, whole team learning review and communication of learning) from Barker and Neailey (1999) and learning process theory (including focus, environment and techniques) from Buckler (1996). Based on these theories, seven aspects were taken into account in the development of the proposed model as follows: (i) learning goal setting; (ii) storytelling; (iii) brainstorming; (iv) reflection; (v) feedback; (vi) knowledge exchange protocol; and (vii) web-based tools.

Proposed continuous project learning model

Figure 1 represents the eight phases of the proposed continuous project learning model during pre-construction stage.

1. Identify subject matter: involves the identification of subject matter in respect to project risks, problem faced or knowledge gap due to the project constraint.
2. Identify learning goals: composed of identification of learning goals based on the expected value and project requirements.
3. Source of knowledge: project team members explore knowledge base of the subject matter and learning goals to identify the available and unavailable knowledge. In general, knowledge base is divided into tacit and explicit form of knowledge.
4. Knowledge sharing session: contains group discussion in the form of brainstorming, reflection, questioning and multi-way feedback sessions.
5. Knowledge application: make and evaluate decisions based on the generation of new knowledge.
6. Knowledge filter and storage: filter and store valuable knowledge generated during the knowledge sharing session in a standard template database that contains project name, subject matter, keywords, expert information and knowledge protocol.
7. Knowledge dissemination, retrieve and update: all project parties communicate and retrieve pertinent knowledge or lesson learned through web-based tool. Knowledge protocol is updated at the end of each knowledge sharing process.
8. Lesson learned linkage: form a continuous learning cycle where any lesson learned, principals or new knowledge from past discussion are linked to subsequent discussion to improve the value of the decision making.

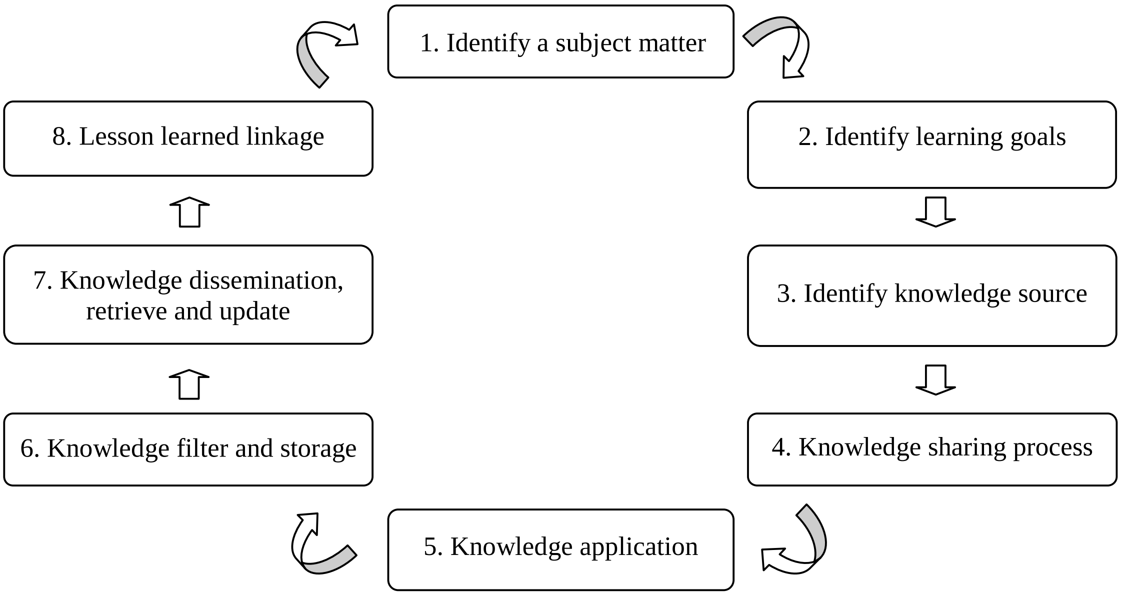


Figure 1: Continuous project learning model

RESEARCH METHODOLOGIES

The study ongoing stage and the research methodologies included the use of literature survey, preliminary interviews and questionnaire survey. Literature survey was performed to outline the current issue in the construction relating to the research area, to find out the knowledge gaps in the pertinent research area, to formulate questionnaire and interview design, and to identify relevant theoretical and empirical information on organizational learning, project learning and learning advantages.

Preliminary semi-structured interviews were conducted for the purpose of exploratory research to extract point of view from contractor firms to understand the existing learning environment in construction projects, to identify the learning methods employed in construction projects and to identify benefits of learning practice. Seventeen construction professionals were randomly selected to participate in the preliminary interview. Preliminary interviews were conducted among a general manager (1), project director (1), project managers (5), contract manager (1), engineers (2), quantity surveyors (6) and administrative executive (1) with two to more than 20 years of experience in construction.

Quantitative questionnaire was selected to collect factual evidence about the organizational learning methods, learning practice in project environment, benefits of each learning methods and the validation of the developed model. The questionnaire method was chosen as it assists the study to generalize findings from a sample to a finite population (Hammersley and Gomm 2000) within a limited time frame (Naoum 1998).

Contractors from Grade 5 to Grade 7 registered with the Malaysian Construction Industry Development Board (CIDB) were targeted as they are involved in a wide range of small to large-scale projects. The study was based on probability stratified sampling method to guarantee adequate representation of groups (Weisberg and Bowen 1977) and the reliability of the sampling design is supported by methods employed in previous studies (Gieskes and Broeke 2000; Love *et al*. 2003). A sample size of 2000 (approximately 27% of total population) private contractor firms in Malaysia was empirically studied. This sample size is considered adequate and excessive based on the sample size table developed by Krejcie and Morgan (1970). The website and the 2005/2006 CIDB directory were used as the sampling frame.

A pilot questionnaire in reference to previous studies (Kululanga *et al*. 1999; Gieskes and Broeke 2000; Fong and Chu 2006) in the field of organizational learning and knowledge management was carried out on a pilot study of 16 construction professionals. The pilot study was conducted either in the semi-structured interviews or in postal survey based on respondents' preferences. Parties participated in the pilot study included project directors (2), project managers (4), contract manager (1), engineers (4) and quantity surveyors (5).

Frequency distribution, percentage distribution and mean were adopted to present the nominal and interval data in an understandable manner. Friedman test, Chi-square and Eta were selected as inferential tests to analyse significant of nominal and interval variables, and the association between nominal and internal data. Data was analysed using Statistical Package for the Social Science Version 13 (SPSS 13.0).

SUMMARY OF PRELIMINARY INTERVIEW FINDINGS

Organizational learning methods

Interviewees were not in general agreement as three interviewees perceived that organizational learning methods can be fully adopted as project learning methods. Fourteen interviewees expressed contrasting views and highlighted that the use of organizational learning methods in construction projects would depend on the project characteristics, size and complexity, the extent of effective of the methods, the capability and willingness of the organization, and the available resources.

Project learning methods
Face-to-face interaction, project meeting, brainstorming, on-the-job training, helping others and referring to previous project were found to be the common methods used by the professionals in the construction.

Improvement elements via project learning practice
Benefits specified by interviewees including encourage individual improvement in respect of knowledge and proficient of task, step up the project value in terms of time, cost and quality, and avoid of “reinvent the wheel”. Few interviewees further commented that the advantages of learning depend on types of information and knowledge, people involved and the types of learning methods.

SUMMARY OF QUESTIONNAIRE FINDINGS

Demographic information
A total of response rate of 5.9% was achieved for the questionnaire survey. Among the respondents, 24 (20.3%) were directors, 12 (10.2%) were general managers, 29 (24.6%) were project managers, 9 (7.6%) were contract managers, 19 (16.1%) were quantity surveyors, 16 (13.6%) were civil and structural engineers and 9 (7.6%) survey respondents held others positions.

Organizational learning methods
Table 2 shows that approximately 65% or above of the total respondents recommended that all the listed organizational learning methods can be implemented in construction projects. Organizational learning methods with response rate of 90% and above include knowledge communities (98.30%), mentoring (97.5%), education (96.6%), professional forum (94.9%) and network of practice, reuse of expert and benchmarking (90.7%). Organizational learning methods that were below 75% were partnering (64.4%), usenet newsgroup (67.8%), electronic conference (69.5%), electronic meeting and chat tools (71.2%) and group document handling (74.6%).

Eta correlation value demonstrates that 13 variables show a medium association and 14 variables shows a high association between the respondents’ recommendations and the extent of effective of the method in knowledge acquisition. Accordingly, variables with 3.50 and above of effective mean value include: education (3.86), mentoring (3.82), knowledge communities (3.72), reuse of expert (3.58), coaching and professional forum (3.58). In contrast, variables with effective mean value below 3.00 include: usenet newsgroup (2.76), chat tools (2.79), electronic conference (2.86), electronic meeting (2.90) and partnering (2.97).

Project learning methods
Table 3 displays the statistical result on the application of learning methods in construction projects. Of the total 118 respondents, learning methods that made up a large proportion of the total response, that is 85% and above were periodic meeting (94.9%), informal face to face interaction (93.2%), problem solving techniques (91.5%), documentation learning (92.4%), internet information searching (89.8%) and imitation (87.30%). Chi-square test for Goodness-of-Fit confirmed that there were significant differences in the results with p-value less than 1% level of significance.

Table 2: Recommendations and effectiveness of organizational learning methods

Organizational learning methods	Recommendations				Effectiveness		Eta correlation	
	Can be adopted		Not recommended		Mean	Rank	Value	Level*
	No.	Percent	No.	Percent				
Knowledge communities	116	98.3	2	1.7	3.72	3	0.461	Medium
Network of practice	107	90.7	11	9.3	3.46	7	0.434	Medium
Professional forum	112	94.9	6	5.1	3.58	4	0.401	Medium
Learning room	104	88.1	14	11.9	3.03	19	0.595	High
Education	114	96.6	4	3.4	3.86	1	0.491	Medium
Mentoring	115	97.5	3	2.5	3.82	2	0.400	Medium
Coaching	106	89.8	12	10.2	3.54	5	0.481	Medium
Integrator	96	81.4	22	18.6	3.06	18	0.608	High
Quality circle	99	83.9	19	16.1	3.43	8	0.644	High
Partnering	76	64.4	42	35.6	2.97	20	0.612	High
Alliancing	92	78.0	26	22.0	3.08	17	0.459	Medium
Reuse of expert	107	90.7	11	9.3	3.58	4	0.429	Medium
Learning contract	103	87.3	15	12.7	3.36	9	0.529	High
Benchmarking	107	90.7	11	9.3	3.31	11	0.480	Medium
Research and development	105	89.0	13	11.0	3.21	12	0.464	Medium
Collaboration with non-construction companies	92	78.0	26	22.0	3.19	13	0.696	High
Intranet	105	89.0	13	11.0	3.32	10	0.587	High
Extranet	98	83.1	20	16.9	3.15	14	0.529	High
Electronic mail	104	88.1	14	11.9	3.53	6	0.526	High
Electronic meeting	84	71.2	34	28.8	2.90	21	0.501	High
Electronic conference	82	69.5	36	30.5	2.86	22	0.584	High
Usenet newsgroup	80	67.8	38	32.2	2.76	24	0.543	High
Discussion list	93	78.8	25	21.2	3.12	15	0.568	High
Group discussion space	99	83.9	19	16.1	3.09	16	0.432	Medium
Chat tools	84	71.2	34	28.8	2.79	23	0.491	Medium
Group document handling	88	74.6	30	25.4	3.05	18	0.503	High
Expert yellow pages	94	79.7	24	20.3	3.08	17	0.434	Medium

Note (Source: Waller 2003): * ≥ 0.1 = low level association; ≥ 0.3 = medium level association; ≥ 0.5 = high level association

Table 3: Results of project learning practice

Project learning methods	Yes		No		Chi-square test	
	No.	Percent	No.	Percent	Value (χ^2)	Significant (p)
Imitation	103	87.3	15	12.7	65.627	<0.001*
Informal face to face interaction	110	93.2	8	6.8	88.169	<0.001*
Creation of new roles	69	58.5	49	41.5	3.390	<0.001*
Periodic meeting	112	94.9	6	5.1	95.220	<0.001*
Debriefing	82	69.5	36	30.5	17.932	<0.001*
Problem solving techniques	108	91.5	10	8.5	81.390	<0.001*
Learn by helping people	98	83.1	20	16.9	51.559	<0.001*
Simulation	52	44.1	66	55.9	1.661	0.197
On the job training	98	83.1	20	16.9	51.559	<0.001*
Job variation	92	78.0	26	22.0	36.915	<0.001*
Trial and error	72	61.0	46	39.0	5.729	0.017*
Extrapolate past events	99	83.9	19	16.1	54.237	<0.001*
Internet searching	106	89.8	12	10.2	74.881	<0.001*
Documentation learning	109	92.4	9	7.6	84.746	<0.001*

* significant, p<0.05

Improvement elements via project learning practice

Table 4 opposite illustrates that not all the learning methods that are commonly applied in construction projects are able to provide a high positive impact towards project value. Five learning methods were perceived as effective approaches if implemented during the pre-construction stage: imitation, informal face-to-face interaction, periodic meeting, problem solving techniques and on the job training. Project constructability was the sole benefit that could significantly be improved among the implementation of five ideal learning methods during the pre- construction stage.

Developed continuous project learning model

Table 5 presents the results of the useful extent of the developed continuous project learning in several aspects. The mean value of the each criterion was sequencing as follows: enhancing knowledge sharing (4.30), enhancing learning and improving individual knowledge seeking (4.26), enhancing communication (4.21), applicable to the current construction projects (4.19), reducing similar mistake (4.14), reducing unnecessary time (4.07) and reducing unnecessary cost (4.04). Friedman test showed that the Chi-square value is 40.583 with p-value less than 1% level of significance. It can be concluded that the developed continuous project learning model is more capable in enhancing knowledge sharing, enhancing learning and improving individual knowledge seeking with mean value above 4.25.

Table 5: Model validation

Validation criteria	Max.	Min.	Mean	Standard deviation	Rank
Applicable to construction projects	3	5	4.19	0.574	4
Enhancing communication	2	5	4.21	0.568	3
Enhancing learning	3	5	4.26	0.633	2
Enhancing knowledge sharing	2	5	4.30	0.618	1
Improving individual knowledge seeking	2	5	4.26	0.646	2
Reducing similar mistakes	1	5	4.14	0.761	5
Reducing unnecessary time	1	5	4.07	0.725	6
Reducing unnecessary cost	2	5	4.04	0.778	7

Friedman test: Chi-square = 31.122, significant, p = 0.001

DISCUSSION

Survey results illustrate that the proposed model tends to be more capable to enhance learning, knowledge sharing and individual knowledge seeking in the construction industry. Drawing on existing arguments, increased profit (Macher 1992) and increased knowledge, which may be either tacit or explicit (Rowley 2000) are after-the-fact indicators that learning is occurring. Accordingly, Winch (2002) affirmed that effective learning within the project deploys the new value creation to the project. Thus, it can be expected that the application of the proposed model during the pre-construction stage is capable to enhance the value of construction projects in terms of time, cost or quality. Nevertheless, it is the significant value of the project is difficult to foresee in reality due to environment, human and other unforeseen factors.

The strength of the proposed model is that it focuses on project knowledge and continuous collective learning in which both elements are critical in enhancing the value of the construction projects. However, the potential shortcomings of this model are that it is built on an unproved premise and the model seems to be suitable for moderate large and complex construction projects.

Table 4: Improvement of project elements via project learning

Project elements		**PL_1**	**PL_2**	**PL_3**	**PL_4**	**PL_5**	**PL_6**	**PL_7**	**PL_8**	**PL_9**	**PL_10**	**PL_11**	**PL_12**	**PL_13**	**PL_14**
1. Time-related elements	Realistic duration for each activity	2.14	2.34	2.00	**2.53***	2.11	**2.35***	2.11	2.12	**2.36***	2.14	1.91	2.19	2.10	2.22
	Better site organization	2.26	2.31	2.04	**2.56***	2.10	2.34	2.15	2.03	2.33	2.13	1.86	2.21	2.03	2.25
	Availability of right resources* at the right time	2.16	2.25	2.00	**2.53***	2.14	2.30	2.08	1.92	2.27	2.13	1.90	2.15	2.08	2.25
2. Cost-related elements	Realistic cost for each element	2.11	2.20	2.06	**2.49***	2.12	2.32	1.97	1.97	2.25	2.16	1.93	2.13	1.99	2.14
	Ability to control cash flow	2.09	2.14	1.98	**2.48***	2.11	2.31	1.95	1.91	2.17	2.03	1.81	2.13	1.96	2.14
3. Quality-related elements	Choice of better construction methods	**2.35***	2.26	2.01	**2.42***	2.21	**2.44***	2.06	2.03	2.31	2.00	1.88	2.24	2.18	2.24
	Safety planning	2.31	2.28	2.04	**2.43***	2.26	**2.37***	2.08	2.15	2.33	2.04	1.81	2.19	2.14	2.20
	Documentation	2.30	2.11	2.00	2.32	2.20	**2.35***	2.03	2.06	2.25	2.06	1.87	2.14	2.14	2.25
	Project constructability	**2.42***	**2.37***	1.99	**2.48***	2.26	**2.43***	2.13	2.13	**2.35***	2.04	1.90	2.21	2.14	2.20
4. Others	Ability to identify risk	2.31	2.27	2.03	**2.43***	2.29	**2.44***	2.08	2.11	2.25	2.08	1.92	2.19	2.08	2.20
	Communication among team members	2.20	**2.51***	2.00	**2.55***	2.19	2.32	2.19	1.91	2.25	2.11	1.91	2.08	2.07	2.03
	Job efficiency (fast and effective)	2.23	2.30	2.05	**2.39***	2.10	2.34	2.13	2.03	2.27	2.08	1.85	2.14	2.06	2.16
	Innovation (coming with new ideas)	2.16	2.35	2.07	**2.42***	2.14	2.30	2.16	1.87	2.20	2.08	1.99	2.19	2.07	2.04
	Reduction of similar mistake	2.24	2.27	1.97	**2.40***	2.22	2.32	2.13	1.99	2.19	2.03	1.92	2.27	1.98	2.11
	Profit	2.08	2.19	1.97	**2.40***	2.08	2.28	2.04	1.96	2.17	2.01	1.82	2.22	2.05	2.14

Notes:

PL_1= Imitation (including observation)
PL_2= Informal face-to-face interaction
PL_3= Creation of new roles
PL_4= Periodic meeting
PL_5= Debriefing
PL_6= Problem solving techniques
PL_7= Learn by helping people
PL_8= Simulation
PL_9= On-the-job training
PL_10= Job variation
PL_11= Trial and error
PL_12= Extrapolate past events
PL_13= Internet information searching
PL_14= Documentation learning

A three-group classification was used based on the average score as follows:
i. Low positive impact (0.00 ≤ mean ≥ 0.67)
ii. Medium positive impact (0.67 < mean ≥ 2.34)
iii. *High positive impact (2.34 < mean ≥ 4.00)

CONCLUSIONS

Although construction industry is fragmented in nature, it has the strength and capability to implement project learning effectively. Results of the survey suggest that: (i) learning within project environment in inter-organizational setting need to be emphasized and top management should play an active role; (ii) a practical system to capture project knowledge is essential; (iii) commitment integration supplements with good leadership from local authority, construction professional and clients play a critical role to the successful implementation of project learning; and (iv) to improve the value of future project, project learning should be integrated into education system to cultivate a conducive learning culture among the junior generation.

The present study demonstrates several limitations, namely: (i) the study was restricted in scope to the local contractor firms in Malaysia; (ii) the study focused only on the preconstruction stage; and (iii) the findings of the questionnaire survey was in infancy stage as the research is in the stage of collecting follow-up data from the non-response respondents and conducting case studies to supplement the quantitative results.

Action research on few construction projects would be able to find out the critical requirements and constraints to increase the level of applicability. Future research into this topic needs to investigate the elements of cross-organizational culture differences against or towards project learning practices.

ACKNOWLEDGEMENTS

The authors highly appreciate the financial support from the Institute of Research, Management and Consultancy (IPPP), University of Malaya for the research grant provided to conduct the study. Special thanks to all the construction industrial professionals for their valuable contribution to this research.

REFERENCES

Abdul-Rahman, H and Berawi, M A (2002) Power Quality System - A new System for Quality Management in Globalization-Towards Innovation and Competitive Advantages. *Quality Assurance*, **9**(1), 5–30.

Abdul-Rahman, H, Berawi, M A, Berawi, A R, Mohamed, O, Othman, M and Yahya, I A (2006) Delay mitigation in the Malaysian construction industry. *Journal of Construction Engineering and Management*, **132**(2), 125–33.

Barker, M and Neailey, K (1999) From individual learning to project team learning and innovation: A structured approach. *Journal of Workplace Learning*, **11**(2), 60–7.

Berawi, M A (2004) Quality revolution: leading the innovation and competitive advantage. *International Journal of Quality & Reliability Management*, **21**(4), 425–38.

Bresnen, M, Edelman, L, Newell, S, Scarbrough, H and Swan, J (2003) Social practices and the management of knowledge in project environments. *International Journal of Project Management*, **21**(3), 157–66.

Brochner, J, Rosander, S and Waara, F (2004) Cross-border post-acquisition knowledge transfer among construction consultants. *Construction Management and Economics*, **22**(4), 421–7.

Buckler, B (1996) A learning process model to achieve continuous improvement and innovation. *The Learning Organisation*, **3**(3), 31–9.

Carrillo, P (2004) Managing knowledge: Lessons from the oil and gas sector. *Construction Management and Economics*, **22**(6), 631–42.

Carrillo, P, Robinson, H, Al-Ghassani, A and Anumba, C (2004) Knowledge management in UK construction: Strategies, resources and barriers. *Project Management Journal*, **35**(1), 46–56.

Chan, P, Cooper, R and Tzortzopoulos, P (2005) Organizational learning: Conceptual challenges from a project perspective. *Construction Management and Economics*, **23**(7), 747–56.

Dell'Isola, A J (1997) *Value engineering: Practical applications for design, construction, maintenance & operations*. Kingston, MA: R.S. Means Company.

Eliufoo, H K (2002) Knowledge transfer: Sustaining knowledge in construction. *In:* O Ural, V Abrantes and A Tadeu (Eds.) *30th IAHS World Congress on Housing*, 9–13 September, University of Coimbra, Portugal. Wide Dreams-Projectos Multimedia, Vol. 1, 83–8.

Fong, P S W (2003) Knowledge creation in multidisciplinary project teams: An empirical study of the processes and their dynamic interrelationships. *International Journal of Project Management*, **21**(7), 479–86.

Fong, P S W and Chu, L (2006) Exploratory study of knowledge sharing in contacting companies: A sociotechnical perspective. *Journal of Construction Engineering and Management*, **132**(9), 928–39.

Fong, P S W and Yip, J C H (2006) An investigative study of the application of lessons learned systems in construction projects. *Journal for Education in the Built Environment*, **1**(2), 27–38.

Gieskes, J F B and Broeke, A M (2000) Infrastructure under construction: Continuous improvement and learning in projects. *Integrated Manufacturing Systems*, **11**(3), 188–98.

Hammersley, M and Gomm, R (2000) Introduction. *In*: R Gomm, M Hammersley and P Foster (Eds.) *Case study method*. London: SAGE Publications Limited.

Hussein, J B (2003) Emerging challenges of project management in Malaysia. *Master Builders*, 4th Quarter, 82–5.

Kadefors, A (1995) Institutions in building projects: Implications for flexibility and change. *Scandinavian Journal of Management*, **11**(4), 395–408.

Kamara, J M, Anumba, C J, Carrillo, P M and Bouchlaghem, N (2003) Conceptual framework for live capture and reuse of project knowledge. *In:* R Amor (Ed.) *CIBW78 20th International Conference on Information Technology for Construction*, 23–5 April, Waiheke Island, New Zealand.

Kamara, J M, Augenbroe, G and Carrillo, P M (2002) Knowledge management in the architecture, engineering and construction industry. *Construction Innovation*, **2**(1), 53–67.

Kotnour, T (2000) Organizational learning practices in the project management environment. *International Journal of Quality & Reliability Management*, **17**(4/5), 393–406.

Krejcie, R V and Morgan, D W (1970). Determining sample size for research activities. *Educational & Psychological Measurement*, **30**, 607–10.

Kristiansen, K, Emmitt, S and Bonke, S (2005) Changes in the Danish construction sector: The need for a new focus. *Engineering, Construction and Architectural Management*, **12**(5), 502–11.

Kululanga, G K, McCaffer, R, Price, A D F and Edum-Fotwe, F (1999) Learning mechanisms employed by construction contractors. *Journal of Construction Engineering and Management*, **125**(4), 215–33.

Leong, J (2006) *Reduction of failures in local construction projects: The roles of consultant, government agencies, professional bodies and authorities*, Published Bachelor thesis, University of Malaya, Kuala Lumpur, Malaysia.

Lin, Y C, Wang, L C and Tserng, H P (2005) Enhancing knowledge exchange through web map-based knowledge management system in construction: Lessons learned in Taiwan. *Automation in Construction*. 13 pgs.

Love, P E D, Irani, Z and Edwards, D J (2003) Learning to reduce rework in projects: Analysis of firm's organizational learning and quality practices. *Project Management Institute*, **34**(3), 13–25.

Macher, K (1992) Organizations that learn. *Journal for Quality & Participation*, 15(7), 8-11.

Naoum, S G (1998) *Dissertation research and writing for construction student*s. Oxford: Butterworth-Heinemann.

Nima, M A, Abdul-Kadir, Jaafar, M S and Alghulami, R G (2002) Constructability concepts in West Port Highway in Malaysia. *Journal of Construction Engineering and Management*, **128**(4), 348–56.

Puddicombe, M S (2006) The limitation of planning: The importance of learning. *Journal of Construction Engineering & Management*, **132**(9), 949–55.

Robinson, H S, Carrillo, P M, Anumba, C J and Al-Ghassani, A M (2004) Developing a business case for knowledge management: IMPaKT approach. *Engineering, Construction and Architectural Management*, 22(7), 733–43.

Rowley, J (2000). From learning organization to knowledge entrepreneur. *Journal of Knowledge Management*, **4**(1), 7–15.

Rowlinson, S (2005) *Value in project delivery systems: Facilitating a change in culture*. Research carried out by The Australian CRC for Construction Innovation, Brisbane.

Storm, P and Savelsbergh, C (2005) Lack of managerial learning as a potential cause of project failure. *In: 18th Scandinavian Academy of Management Meeting*, 18–20 August, Aarhus, Denmark.

Tserng, H P and Lin, Y C (2004) Developing an activity-based knowledge management system for contractors. *Automation in Construction*, **13**(6), 781–802.

Waller, J T (2003) *The effectiveness of probation in West Virginia: A study examining the practices and views of probation officers in West Virginia*, Unpublished Master thesis, Marshall University.

Watson, G H (2005) Putting value back into engineering. *ASQ World Conference on Quality and Improvement Proceedings*, **59**, 163–74.

Weisberg, H F and Bowen, B D (1977) *An introduction to survey research and data analysis*. San Francisco: Weisberg, Herbert Freeman and Company.

Winch, G M (2002) *Managing construction projects*. Oxford: Blackwell Publishing Limited.

Woudhuysen, J and Abley, I (2004) *Why is construction so backward?* Singapore: John Wiley & Sons (Asia) Pte. Ltd.

LESSONS LEARNED PRACTICES: CASE STUDY OF A LEADING IRISH CONSTRUCTION ORGANIZATION

Brian Graham[1] **and Ken Thomas**

Department of Construction and Civil Engineering, Waterford Institute of Technology, Waterford, Republic of Ireland

The implementation of lessons learned (LL) practices within construction organizations are viewed as an important part of knowledge management (KM), having the potential to improve the outcomes of a project. PJ Hegarty & Sons, a leading Irish construction organization, has recently implemented such practices as part of the Engineers Ireland Continuing Professional Development (CPD) accreditation scheme. The purpose of this paper is to identify and evaluate the adopted practices, which include a LL database, supported by LL seminars. Adopting a case study methodology, a survey and in-depth interviews with a broad spectrum of management and professional staff was conducted, including a director, project managers, quantity surveyors, foremen and engineers. It was found that the delivery of LL requires careful consideration of its intended users. In addition to integrating LL practices into existing organizational procedures, notification of new lessons and continuous training on the use of the database are required. Delivery of LL seminars should be focused at project-level and conducted on site to support both individual and organizational learning. The use of both technology and face-to-face interaction is important in the success of LL, particularly in aligning individual learning with that of the organization.

Keywords: case study, construction organization, continuing professional development, knowledge management, lessons learned.

INTRODUCTION

The construction industry is facing numerous challenges; increasing competition, globalization of the construction market, increased demands from clients and society, the impact of new technology, and the requirement to maintain a highly skilled workforce at all levels (Egbu and Robinson 2005). Indeed as a highly knowledge-intensive industry, with specialized expert knowledge and problem solving know-how to the fore, the industry requires a more structured approach to managing knowledge (Egbu and Robinson 2005). Knowledge management (KM) has been promoted as a means of harnessing and utilizing intellectual resources to address these challenges, yet there remains uncertainty about how to devise and implement a viable and cost effective KM initiative in practice (Kamara *et al*. 2002). Embracing the information systems and human resource management strands of discourse, KM is defined from an integrated perspective by Jashapara (2004: 12) as: “the effective learning processes associated with exploration, exploitation and sharing of human knowledge (tacit and explicit) that use appropriate technology and cultural environments to enhance an organization’s intellectual capital and performance.” However, due to its project-based, fragmented and unstable nature, the construction industry is recognized as

[1] bgraham@wit.ie

being poor at learning on a consistent basis and improving performance and is notoriously slow in adapting to progressive change (Orange *et al*. 2003). It is now recognized that there may be much greater potential for KM within individual companies as opposed to temporary project teams (KLICON 1999).

Lessons learned (LL) practices are an important aspect of KM. LL practices refer to "the activities, people and products that support the recording, collection and dissemination of lessons learned in organizations" (Snider *et al*. 2002: 291). The purpose of LL is to capture experiences, successful or otherwise, allowing an organization to avoid repeating costly mistakes, improve future performance and ultimately, the contractor's profit (Carrillo 2005; Kartam 1996). In a study of American contractors, Fisher *et al*. (1998) identified a number of other reasons for implementing a formal LL process as: high staff turnover leading to loss of experience; large size of organizations make sharing knowledge difficult; and departmental silos and fragmentation within the organization. Two key issues were identified by Kartam (1996) in the development of LL practices, a manageable format for organizing, storing, retrieving and updating information and an effective mechanism for collecting, verifying, categorizing and storing information. In devising such practices, Robinson *et al*. (2005) identify two distinct strategies: codification and personalization. Codification involves capturing knowledge in an explicit form and leveraging it using IT tools such as a LL database (LLDB). Personalization focuses on sharing tacit knowledge through human interaction. While a combination of both codification and personalization is most appropriate (Kamara *et al*. 2002; Fisher *et al*. 1998; Voit and Drury 2006), there has been a scarcity of solutions about how to effectively marry social processes with technology (Dixon 2004).

Based on the accepted potential for KM within a construction organization, the objective of the reported research is to identify and evaluate LL practices within a leading Irish construction organization through a case study methodology with the aim of identifying LL practices can be improved.

THE LESSONS LEARNED PROCESS

Fisher *et al*. (1998) developed a LL process comprising the following three stages.

Collection

The identification and capture of a LL is an extremely difficult process, with a variety of tools identified such as post-project reviews and debriefing (Disterer 2002; Kartam 1996). Two approaches have been identified for collection of LL; "a 'sought input' type collection process, where a custodian of the LLP obtains input from various agencies" (Fisher *et al*. 1998: 45) and a requirement for individuals to submit LL themselves (Kartam 1996).

Analysis

A LL must be significant in that it will have a real impact, valid in that it is factually and technically correct and applicable in that it identifies something that eliminates the potential for future failures or reinforces a positive result (Weber and Aha 2002). The analysis of contributed LL is vital considering that "construction practitioners will not accept an assertion that a certain method is superior to another, without a sound rationale" (Kartam 1996: 19). Fisher *et al*. (1998) recommend that analysis of LL be carried out by a team of senior staff with extensive industry experience. In documenting a LL, Kartam (1996) identifies three key components required, a title describing the lesson, information regarding the source and context from which the lessons is collected, and a means for sufficiently classifying the lesson in a manner that allows fast, clear retrieval by multiple parameters.

Implementation

The dissemination of LL can occur by two methods, push and pull. Push methods deliver the LL directly to the user based on their role, interests, training and experience, while pull methods leave the burden of search to the user, who must devote their attention to the source (Weber and Aha 2002). In this context, Weber and Aha (2002: 292) discuss the distribution gap which refers to "the difficulty of transmitting lessons between a lessons learned repository and its prospective user." This can occur for a number of reasons: distribution is not part of organizational processes, users may not know or be reminded of the repository, users may not have the time or skill to retrieve and interpret textual lessons, and subsequently apply the lessons successfully (Weber and Aha 2002). A study by Fong and Yip (2006) identified e-mail or written documents as the most suitable distribution channels for lessons to construction professionals, intranets or websites being the least suitable.

IMPLEMENTING LL PRACTICES

In attempting to implement LL practices and indeed other KM initiatives, a number of challenges have been identified (see Table 1 for LL specific challenges), including poor organizational culture, lack of top management support, lack of dedicated resources such as staff, time and money, and poor ICT infrastructure (Fisher *et al*. 1998; Snider *et al*. 2002; Kartam 1996; Carrillo 2005; Weber and Aha 2002).

Table 1: Challenges in adopting LL practices in construction

Lack of time to capture and use learning experiences
Usually captured at the end of the project when many people have moved on
Loss of insight due to lime lapse between lesson and recording
Failure to uniformly document LL in a useful manner
Lack of proper classification system
Difficulty integrating with existing operations and procedures
Difficulty sharing lessons between experienced and inexperienced individuals
No motivation or perceived benefits for individual employees
Failure to deliver lessons when and where they are needed
Requires people to internalize LL and apply them at work
Difficult to measure and communicate benefits

To improve LL practices, Davidson (2006) advises that the lessons should be regularly reviewed to ensure accuracy, reliability and relevance, incorporate appropriate LL into business processes, training and checklists, educating people to use the LLDB, demonstrate the value in sharing LL and provide positive feedback to contributors and users. Voit and Drury (2006) identify two key aspects of LL programs as influencing program effectiveness, information usefulness and human intermediary activities. Information usefulness is the perceived usefulness of the lesson learned, particularly in relation to an individual's current job responsibilities. To reinforce the importance of the LL program, human intermediaries (e.g. managers) should monitor and review their staff's use of the LL. In order to create an environment conducive to learning, senior management need to visibly support an LL initiative, assess the organization's culture, eliminate barriers, set goals, get departmental buy-in, designate a champion, empower workers, allocate resources, and measure and track results (Robinson *et al*. 2005; Fisher *et al*. 1998).

LINKING LL TO CPD

A central problem of promoting learning across an organization is that despite people acting collectively, they actually learn individually (Kleiner and Roth 1997). Terrell (2000) contends that far from being learned, lessons are at best, observed, particularly in project-based organizations who have found it extremely difficult to capture and reuse the LL (Dixon 2004). In order to move beyond this, Dixon (2004: 18) believes that LL need to be connected to social processes, "the development of relationships, reflective conversations, probing questions and in-depth interactions – that are the backbone of knowledge sharing." In an attempt to address this issue, Turner Construction has devised a knowledge network to develop and train individual employees, aligning learning with the overall business strategy, improving both individual and organizational performance. Adopting a blended learning approach, Turner utilizes its own experiences and knowledge to develop both face-to-face and web-based CPD courses for its staff (Lemons 2005). Training is viewed as an important part of LL practices, in promoting the use and benefits of LL practices and incorporating actual LL into training (Fisher *et al*. 1998; Fong and Yip 2006).

THE IRISH CONSTRUCTION INDUSTRY

Considered "the most important part of Irish economic growth", the overall output of the industry in 2006 was €36bn, accounting for 24% of the country's GNP, with over 12% of the country's workforce directly employed (Davis Langdon PKS 2006: 3). The industry is however, facing a number of challenges: the introduction of fixed price government contracts, an increase in the number of foreign-based firms entering the market, over-reliance on the housing market and a predicted slowdown in construction output in the coming years (DKM 2006). Documented low levels of R&D and innovation in this important industry need to be addressed through improved knowledge transfer and creative thinking (Kelly 2005; CIF 2004). In this regard, the Forum for the Construction Industry, Engineers Ireland and the Construction Information Technology Alliance (CITA) have all cited the strategic importance of KM and its contribution to the knowledge economy.

ENGINEERS IRELAND

Ireland's largest professional body Engineers Ireland (EI) have introduced a CPD accreditation scheme for employers of engineers across a spectrum of industries. Twelve of the top twenty Irish construction companies are currently engaged in the accreditation process, of which three are fully accredited. Specifically defined criteria have been established, against which accreditation of companies is considered: CPD policy, performance management system, CPD activity, recording of CPD, mentoring, involvement with professional institutions, KM system and management control system. It is reasonable to suggest therefore that CPD has an important role to play in KM within construction, at individual, project and organizational levels.

RESEARCH METHODOLOGY

A case study methodology was adopted to evaluate LL practices within PJ Hegarty & Sons (PJH), a leading Irish construction organization. Such an approach was chosen as it seeks a range of different kinds of evidence in a case setting, which when abstracted and collated has the potential to provide the best possible range of answers (Gillham 2000). This study forms part of a wider research project investigating KM in the leading 20 Irish construction organizations as they are perceived to exert the most influence on the approach to managing construction projects and the industry in general (Thomas 1999). Following an interview with a director from PJH in January 2006, the possibility of conducting some in-depth research emerged leading to the design of a questionnaire. Administered between February and April 2006, the purpose of the questionnaire was to explore the effectiveness of identified KM initiatives such as the LL database and seminars, CPD, and communications within the company's Dublin office. Follow-up interviews were then conducted with the full site team on a €70m design and build, commercial development project based in Waterford between May and June 2006.

CASE STUDY RESULTS AND ANALYSIS

Founded in 1925, PJH had a turnover of €320 million in 2006, making them the sixth largest Irish contracting company. Employing in excess of 700 staff, the company undertake a range of large construction projects throughout Ireland from offices located in Dublin, Cork, Limerick and Galway. In 2004, PJH became the first construction company in Ireland to be awarded EI accreditation for CPD.

The questionnaire was distributed to 180 professional and management staff via email, achieving a 36% response rate. As can be seen in Table 2, the survey respondents have a range of experience of working in the construction industry, with over a third having less than five years experience. Conversely, 69% of the respondents have been working with PJH for less than five years. Notwithstanding the 37% with less than five years' industry experience (mostly recent graduates), this may be due to the highly competitive nature of the industry at present, presenting considerable work opportunities to the industry's workforce. Coupled with a relatively young workforce (63% are 35 or under), this low level of experience within the company highlights the need for effective LL practices to improve both the individuals and the organizations knowledge base. The follow-up interviews were conducted with 13 staff members, comprising a senior contracts manager, a project manager, three quantity surveyors, three engineers, four foremen and the site safety advisor all based on site in Waterford.

Table 2: Survey respondents' industry experience

	< 5 years	5–10 years	11–20 years	>20 years	Total
Working in construction	37%	25%	14%	24%	100%
Working for PJH	69%	21%	8%	2%	100%

Overview of lesson learned practices

Based on the initial interview with a director, it was found that PJH had implemented LL practices as part of the KM requirement for CPD accreditation, comprising a LL database (LLDB) and LL seminars. The LLDB is managed by the company's quality and administration manager on a part-time basis. Based in the Dublin office, the LLDB administrator has over 30 years' experience in the construction industry, nine of which have been spent with PJH and is responsible for providing training on the LLDB when new recruits join the company.

The lessons learned process

- *Collection*: chaired by a director, PJH conduct a post-project review for all projects where key members of the project team discuss the best and worst experiences. The loss of experience due to time lapse is addressed by interim review meetings which are held every 6 months and "these would be reviewed as part of the end meeting…it's really at the end of the job that you look back and say 'what are the big issues here?' I mean you can't log everything, if you catch the big issues, you're doing well." In this regard, he added: "at the end of the day our business is building, where do you stop with these initiatives…we try to do our best with the LL, but there's only so much you can do."

- *Analysis*: following the review, the key LL are documented by the contracts manager in a standard template detailing the title, description of the LL and contact details for individuals involved, and is classified based on the trade/subcontract package with which it is associated. Once completed, it is sent to the administrator, and if acceptable it is posted on the database, if not it may be sent back to the source for further clarification or edited by the administrator himself.
- *Implementation*: the archived LL are disseminated via two methods, pull methods occur in the form of a LL database (LLDB), a central repository that can be accessed from all offices and sites by logging into the company's network, the use of which is not measured and tracked by management. The company director acknowledges that "you are depending on people to take the time to look at the database. We also give seminars based on lessons learned on a fairly regular basis to support the database." In conjunction with the HR department, the LL administrator organizes LL seminars based on a selected trade or subcontract packages for staff, and on some occasions delivers them himself. These seminars are usually delivered in the training room of the Dublin office in the evening time.

Evaluation of lessons learned practices

Lessons learned database

According to the director, *"the theory is, and I'd be interested in the answer from your survey on this one, is that before you start a particular package you log onto the database and have a look, in the hope that you don't make the same mistake again."*

Table 3: Frequency of use of LLDB

Rank	Use of LLDB	%
1	Very rarely	34
2	When I have a specific query/problem	27
3	Never	15
4	Quite often	13
5	When a new subcontract package starts	11

Despite nearly three-quarters of the survey respondents (74%) stating that they found it beneficial to them in their work, Table 3 shows that *very rarely* ranked highest in terms of usage, with *when a new subcontract package starts* ranking lowest at 11%. During the interviews, the use of the LLDB was discussed, the following being the most pertinent issues identified:

- *Lack of time*: many respondents stated that they just didn't have the time to look through the database every time a new package started. "I haven't checked it in about a year…you don't get time to, unless you're sitting here twiddling your thumbs…it's extremely difficult when you're out on site all day."
- *Relevance to current role*: some people questioned the actual relevance of LL to them in their current position. One respondent stated "a lot of the things on

the lessons learned are relevant to foreman…they're the guys out there dealing with those issues…that's where the breakdown is, the people who really need to know don't have access to a computer, its not in their job description."

- *No requirement to contribute*: many people stated that there was no requirement on them to contribute to the LLDB, and as a result, didn't bother. One individual suggested "perhaps contributing to the lessons learned should be part of your work. The company I worked for in England did that, when you did your monthly report for the directors, you had to do your lessons learned."
- *Difficulty finding the most recent lessons*: the lessons are not categorized by date, "you have to sift through the older lessons as well." Indeed, 42% of the survey respondents ranked this issue as the most problematic factor in using the database.

In considering how to improve the use of the LLDB, a number of the interviewees contended that there should be refresher courses run, as most people felt that being shown how to use the LLDB on their first day with the company was not effective.

Lessons learned seminars
The LL seminars provided by PJH can count towards CPD hours with a variety of professional bodies, offering incentive for staff to attend. The survey found that 8% of respondents don't attend any seminars, 53% attend between 1 and 4, 31% attend between 5 and 9, with 8% attending 10 or more seminars each year. A number of problems with the seminars were identified in the interviews as:

- *Timing and location of seminars*: the seminars are run in the evening in the Dublin office, after a "hard day's work on site." Many of the interviewees cited fatigue and long travelling times as being counter-productive to getting any value out of the seminars. "We were out working in the rain one day, a big concrete pour…and then I'm into this thing at 5.30…and I mean the heat and all, I'd been out in the fresh air all day, out in the wind, and I come into this nice, cosy, comfortable room to a guy in a shirt and tie…and I'm gone!" One interviewee suggested that "there should be more done on-site, particularly on a big site like this where you have a lot of staff…it's not a thing that has to happen in head office."
- *Delivery of seminars*: "the likes of the office people would be giving a seminar on lessons learned…they talk about them, but because they're not involved on site, they don't come up with any solutions."
- *Relevance*: it is important that seminars are pitched at the right level to the audience "if it's not relevant or you know it already, you're going to switch off," a recurring theme in the interviews, people cited this aspect as putting them off attending again.
- *Experience of attendees*: a graduate engineer felt that they didn't gain a lot from seminars covering issues they hadn't yet encountered on site "once you've seen it been done, I find it's easier to go to a seminar and talk about it…it's hard to visualize something that you've never seen or experienced when you go into a room and listen to someone talk about it for an hour."

DISCUSSION

Based on a case study of LL practices within PJH, this section aims to highlight the strengths and weaknesses of their approach to LL with a view to identifying how construction companies can improve such practices.

The lessons learned process

- *Collection*: a *sought input* collection process is used, whereby the director responsible for the project in question facilitates a post-project review. This end of project review is augmented by interim review meetings during the course of the project and aims to capture the *big issues* related to the project.
- *Analysis*: the LL is analysed and documented on a standard template by the contracts manager, before being sent to the LLDB administrator for further analysis. The documentation of the LL appears to meet Kartam's (1996) recommendations for a title, contextual information and classification, although perhaps the LL should be review by a wider group prior to acceptance as recommended by Fisher *et al*. (1998).
- *Implementation*: both push and pull methods are utilized by PJH in disseminating LL, through seminars and a database respectively.

The process adopted by PJH focuses on capturing the main LL from each of their projects, as the director indicated that it would be difficult to capture all LL from a project. In order to improve this process and capture more LL, further integration with existing organizational practices is required.

Lessons learned database

The use of the LLDB is not monitored by company management, nor are staff required to use it as part of their work, leading to a distribution gap between the database and prospective users. Site-based staff do not dedicate time to using the LLDB as they view their work as being out on site, not at a computer, yet it is precisely these people who should be using it. Finding the most recent LL's were difficult as they were not categorized by date; a more robust classification and search functionality may address this. A simple email system notifying staff in relevant positions of new LL could potentially improve the dissemination of LL. Incorporating the use of the LLDB into company policy, linking use to subcontract awards, and requiring certain key project members to contribute a LL with their monthly reports could improve both collection and implementation of the LLDB.

Lessons learned seminars

To improve the dissemination of LL, CPD seminars are organized in the company office for staff to attend after work. The timing and location of these was found to be problematic for staff who had to travel to the office from site. Furthermore, the people who delivered the seminars were not necessarily those who had actually experienced the lessons learned, thus limiting their knowledge of the context within which the lesson originated. This highlights the problems of actually learning from a documented LL as discussed by Terrell (2000). The experience of people attending the seminars and the relevance of the LL to their work were other issues highlighted as being important. To improve the effectiveness of the seminars, they could be delivered on site to the project team as and when they are relevant. For example, conduct an LL seminar on glazing a week before the glazing subcontractor begins on site with all members of the project team, including foremen.

Linking lessons learned to CPD

The linking of the LL seminars to individual CPD appears to be a step in the right direction, the role of human intermediaries in reinforcing the importance of LL, vital. Collaboration between contracts managers, the HR department and the LLDB administrator, in the delivery of on-site LL seminars as part of CPD activities is required. Further integration of the LLDB and the LL seminars into a blended learning programme may enhance the effectiveness of delivering LL within the organization. In addition, there is now a need for the company to implement a system to track and measure the use and effectiveness of these practices and to communicate benefits throughout the organization.

CONCLUSIONS

The LL practices of a leading Irish construction organization have been identified and evaluated, with a view to making recommendations for other firms considering implementing LL. These practices were investigated in relation to the process used to collect, analyse and implement LL, exploring implementation through a LLDB and LL seminars. Based on this investigation, the following conclusions can be made:

1. Carefully design the LL process and integrate it into existing organizational procedures. The *collection* of LL should incorporate both a sought input and a requirement for individual contributions. Submitted LL should be *analysed* by a number of people, be consistent in their structure and classified by a number of parameters, particularly roles to which the LL is relevant. *Implementation* of LL should combine both push and pull methods, targeting specific staff members through direct distribution.
2. Use of a lessons learned database should be incorporated into existing organizational practices with careful consideration given to the classification system used, particularly based on date of LL. Emails and memos notifying staff of new LL and reminding them to use the database, in addition to refresher courses on the use of the LLDB are also recommended.
3. LL seminars should be organized for staff to augment the LLDB, with careful thought given to the timing, location and delivery of them. Site-based seminars may be more appropriate and relevant on large projects, which can be linked to current and upcoming subcontract and trade packages on site.
4. The integration of LL practices with CPD has the potential to align both individual and organizational objectives. The development of a blended learning approach to delivering and promoting LL merits further investigation, particularly in addressing the need for site-based CPD activities.

While LL practices have the potential to improve the performance of construction organizations, there has been little documented evidence of such improvements in practice. This paper has identified and evaluated LL practices within a leading Irish construction organization, highlighting a number of issues in relation to its implementation that may well be of benefit to other construction organizations in Ireland and overseas.

REFERENCES

Carrillo, P (2005) Lessons learned practices in the engineering, procurement and construction sector. *Engineering, Construction and Architectural Management*, **12**(3), 236–50.

Construction Industry Federation (2004) Construction Industry Federation website: http://www.cif.ie (accessed May 2005).

Davidson, J (2006) Finding the value in lessons learned. *KM Review*, **9**(3), 6–7.

Davis Langdon, PKS (2006) *Irish Construction Annual Review 2006*. Available online: http://www.dlpks.ie

Dixon, N M (2004) Does Your Organization Have An Asking Problem? *KM Review*, 7(2), 18–23.

DKM (2006) *Review of the Construction Industry 2005 and Outlook 2006–2008*. Dublin: DKM Economic Consultants.

Egbu, C and Robinson, H (2005) Construction as a Knowledge-Based Industry. *In:* C Anumba, C Egbu and P Carrillo (Eds.) *Knowledge Management in Construction*. Oxford: Blackwell Publishing.

Fisher, D, Deshpande, S and Livingston, J (1998) *Modelling the Lessons Learned Process: A Report to the Construction Industry Institute*, The University of New Mexico, Albuquerque, New Mexico, Research Report 123-11, January.

Fong, P S W and Yip, J C H (2006) An Investigative Study of the Application of Lessons Learned Systems in Construction Projects. *Journal for Education in the Built Environment*, **1**(2), 27–38.

Gillham, B (2000) *Case Study Research Methods*. London: Continuum Books.

Jashapara, A (2004) *Knowledge Management: An Integrated Approach*. London: Prentice Hall.

Kamara, J M, Augenbroe, G, Anumba, C J and Carrillo, P M (2002) Knowledge management in the architecture, engineering and construction industry. *Construction Innovation*, **2**(1), 53–67.

Kartam, N A (1996) Making Effective Use of Construction Lessons Learned in Project Life Cycle. *Journal of Construction Engineering and Management*, **122**(1), 14–21.

Kelly, K (2005) Innovation in the Building Industry. *The Engineers Journal: Journal of the Institution of Engineers of Ireland*, **59**(2), 83–5.

Kleiner, A and Roth, G (1997) How to Make Experience Your Company's Best Teacher. *Harvard Business Review*, **75**(5), 172–7.

KLICON (1999) *The Role Of Information Technology In Knowledge Management Within The Construction Industry*, Project Report of Knowledge Learning in Construction Group at the Centre for Research in the Management of Projects, University of Manchester Institute of Science and Technology.

Lemons, D (2005) Integrating KM and Learning at Turner. *KM Review*, **8**(2), 20–4.

Orange, G, Onions, P, Burke, A and Colledge, B (2003) *Knowledge Management: Facilitating Organisational Learning within the Construction Industry*, Discussion Paper, School of Information Management, Leeds Metropolitan University.

Robinson, H, Carrillo, P, Anumba, C and Al-Ghassani, A (2005) Knowledge management practices in large construction organisations. *Engineering, Construction and Architectural Management*, **12**(5), 431–45.

Snider, K (2002) Considerations in acquisition lessons-learned system design – Lesson Learned. *Acquisition Review Quarterly*, winter.

Thomas, K (1999) *The Influence of the Leading Firms on the Exploitation of IT in the Irish Construction Industry*, unpublished paper, presented at conference: Potential of Information Technology in the Construction Industry, 19 November, Dublin Institute of Technology.

Voit, J R and Drury, C G (2006) Supporting Vicarious Learning With Collaborative Lessons Learned Programs. *IEEE Transactions on Systems, Man and Cybernetics*, **36**(6), 1054–62.

Weber, R O and Aha, D W (2002) Intelligent delivery of military lessons learned. *Decision Support Systems*, **34**(3), 287–304.

EVALUATION OF THE BENEFITS OF AN ONLINE CONTRACT CHANGE MANAGEMENT SYSTEM FOR NEC/ECC PROJECTS

Ming Sun[1], Tejas Oza[1] and Robin Wilkin[2]

[1]*Faculty of the Built Environment, University of the West of England, Coldharbour Lane, Bristol, BS16 1QY, UK*

[2]*Management Process Systems Ltd, 4 The Lanterns, Melbourn Street, Royston, Hertfordshire, SG8 7BX, UK*

The Contract Change Management (CCM) system is an online service, purpose-designed to support the project management processes of the NEC/ECC (New Engineering Contract/Engineering and Construction Contract) form of contract. Anecdotal evidence suggests that the system helps projects reduce risks and save costs. This study seeks to ascertain the key benefits of CCM from the user perspective, through a questionnaire survey. A questionnaire was sent to 260 randomly selected CCM users and 85 (33%) valid replies were received. The results showed that there is a high degree of consensus of the benefits of the CCM system in eight key project management aspects: process improvement; business improvement; risk management; communication; management information; efficiency; collaboration/partnering; and traceability. However, there are also some different opinions on what the most important benefits of the system are from different groups of users, i.e. clients, contractors and consultants.

Keywords: contract management, information technology, partnering, project management, statistical analysis.

INTRODUCTION

Traditionally, project changes and variations often cause disputes, claims, delays and cost overruns in the construction industry (Arain and Pheng 2005; Ibbs 1997; Love and Li 2000). Changes can be caused by a variety of factors, such as site conditions, climate, design changes, client requirement changes, communication failures, poor site management, external conditions, etc. Some of these factors are beyond the control of the project team. All they can do is to be prepared for the inevitable changes in order to minimize any negative impact. In most cases, the earlier a potential change is identified the easier it can be dealt with. The NEC/ECC contract (Mitchell and Trebes 2005), initially published in March 1993, seeks to address project change management through encouraging good management process and better collaboration between all parties involved in the decision making process. NEC/ECC requires the principal parties to notify each other as soon as certain conditions become apparent, which may lead to project changes at a later stage. This is called an Early Warning (EW) because it allows the team time to consider their options to deal with the risk, before it impacts on the project's timescales, costs, safety, or quality. During NEC/ECC projects, the team is required to hold regular EW (also known as risk

[1] ming.sun@uwe.ac.uk

reduction) meetings to review all known risks and consider action. When a change risk is identified, the project manager (PM) usually needs to issue an instruction to the contractor to deal with the risk or carry out necessary change. If the change has an impact on cost and/or schedule, it will be regarded as a “compensation event”. The contractor is then required to provide a quotation for the work, including costs for any time-related works caused by any delays. The response period for this is usually three weeks, although this may be extended. The PM then has two weeks to accept the quotation, seek resubmission due to incorrect assessment, or carry out a PM assessment. The quotation value is then implemented or added to the total price, or target cost in some cases. In most projects, the commercial and programme impact of a PM instruction (PMI) is usually considered and partially agreed at the EW meeting.

Although the process of change management under NEC/ECC is well defined, its successful execution in practice relies on good communication and information sharing between the parties, as well as robust support for the decision making process. These are difficult to be achieved without the support of an appropriate tool. The Contract Change Management (CCM) system is an online application specifically designed to support the change management process for projects that adopt the NEC/ECC form of contract. The system manages the life cycles of all notices issued by the NEC/ECC contract, in a collaborative environment over the Internet. These include EW, PMIs, notification of compensation events (CE), quotations, PM assessments, implementations, and a variety of PM/contractor communications. All documents are user and date stamped and held in an audit trail. The impacts of CEs are monitored against the activity schedules for each work package, in order to ensure that the adjusted target price and target completion date are up to date. The system is available to all registered users over the web, and is password protected. The key business improvement benefits of CCM include: (1) increased productivity by improving communication efficiency; (2) improved predictability of outcome (cost & time); (3) reduced project risk; (4) better compliance with contract requirement; and (5) process visibility and auditability.

During the last few years, the CCM system has been used by a growing number of companies in the UK. Many users are convinced of the benefits of CCM in helping them reduce risks and save costs based on anecdotal evidence. There is a desire by both the CCM service provider and its users to ascertain the benefits of the system through a user survey. The aim is to establish: (1) does the system deliver the benefits it promises in practice; (2) what are the most important benefits from the user perspective; and (3) are there any differences between different user groups?

QUESTIONNAIRE SURVEY

In recent years, there is a growing interest in the evaluation of IT benefits in construction. Numerous evaluation frameworks have been proposed by CIRIA (1996), Construct IT (1998), Li (1996), Marsh (2000), etc. However, empirical studies of IT benefits in practice are rather limited. Stewart (2003) reported a user survey study aimed at evaluating the value of IT adds to the process of project information management in construction. A similar study was conducted by Love (2005). Both authors recommended questionnaire survey as a useful instruction for such a study.

The study also adopted the questionnaire survey approach. A questionnaire was developed, which contains questions in five sections:

- Profiles of the respondents and their organizations.

- Respondents experience with NEC/ECC contract and the CCM system
- Evaluation of the benefits of CCM.
- Evaluation of functional aspects of CCM system.
- Evaluation of the quality of the service provider.

Details of the questions will be explained in the following analysis of survey results. A total of 260 users were randomly selected from the existing CCM user database. A pilot study was carried out with five selected users. As a result, some minor adjustments were made to some of the questions before the questionnaire was sent out. However the changes are not significant. Therefore, the five responses of the pilot were included with 80 responses received during the main survey. This makes the total number of valid responses 85, representing a return rate of 33%.

ANALYSIS OF SURVEY RESULTS

Profiles of respondents

- The responses to the survey included Main Contractors (40%), Client Organizations (21%), Consultant Quantity Surveyors (15%), Project Management Consultants (14%) Architect/Design/Engineering (5%), and Specialist Sub Contractors (1%), as well as ‘Others’ (4%).
- According to disciplines, the responded group included Project/Contract Managers (41%), Quantity Surveyors (19%), Directors/ Senior Managers (15%), Commercial Managers (11%), Supervisors/ Clerk of Works (4%), Architect/ Design/ Engineering (1%) and ‘Others’ category (9%).
- Almost all respondents have broadband Internet access: 92% of respondents have Internet access at work; 46% can access using laptop; 62% have home Internet access; and 27% use Internet from other business offices.
- Approximately 31% of respondents have over 25 years of experience in the construction industry, another 31% have 16–25 years and 32% have 6–15 years. A small number (under 7%) have 0–5 years of experience. (or 94% of respondents have more than six years experience in the industry)
- Most of the respondents have used the NEC/ECC form of contract. Amongst them, 24% have used NEC/ECC on over six projects; 29% have used it on 4–6 projects and 44% have used NEC/ECC on 1–3 projects.
- 94% of the respondents have used CCM on their projects. The number of projects on which they used the system varies. CCM supports two types of users: Active User (who can enter information into the system) and Read Only User (who can only read and download information from the system); 74% of the CCM users surveyed were Active Users (they might also be Read Only users on different projects) and 26% are Read Only users.
- 12% of the respondents are using CCM at Initial stage of their project; 35% at Mid stage; and 29% at the End/Closure stage – 19% are not currently using the system.
- 30% of all respondents use CCM up to an hour per week; 35% use it for 1–3 hours; 25% use for 3–5 hours; 5% use 5–8 hours and 5% use it for more than eight hours per week. However, the usage varies between client, contractor and consultant users, as well as between different project stages.

Respondents' views on the benefits of CCM

Prior to the survey, a list of 43 potential benefits was identified based on anecdotal evidence. These benefits were included in the questionnaire under eight categories: (1) Process improvement; (2) business improvement; (3) risk management; (4) communication; (5) management information; (6) efficiency; (7) collaboration/partnering; and (8) traceability. The respondents were asked to rate each benefit. The question in the questionnaire reads: "anecdotal evidence indicates CCM offers the following benefits. Do you agree?" For each benefit, the respondents were asked to click one of four possible answers: "Strongly agree", "Agree", "Disagree" or "Strongly disagree". Respondents were asked to answer as many questions as they can, if they could not answer all of them. In the following analysis, a numeric score is assigned to each answer: Strongly agree – 4, Agree – 3, Disagree – 2, and Strongly disagree – 1.

Tables 1–8 show the results of the benefits survey. In each table, the percentage of responses for each answer is shown together with a mean score and standard deviation value for every benefit. For example, Table 1 shows the results for the benefits related to process improvement. For the benefit "1.1 Quality assured change management process", 2% of the respondents answered "Strongly disagree", 9% of them answered "Disagree", 65% answered "Agree" and 24% answered "Strongly agree". This gives this benefit a mean score of 3.11 and standard deviation of 0.65. Under this scoring scheme, the minimum value is 1, which represents 100% "Strongly disagree" with the existence of that benefit. Maximum value is 4, representing 100% "Strongly agree". The median value is 2.5. Any mean score greater than 2.5 represents a positive feedback.

Table 1: Benefits of process improvement

Benefits	(1)	(2)	(3)	(4)	Mean	SD
1.1 Quality assured change management process	2%	9%	65%	24%	3.11	0.65
1.2 Rigorous process for management of change	1%	7%	66%	26%	3.16	0.60
1.3 IT support ensures the automated flow of work (workflow) against an agreed baseline and organization structure	3%	19%	65%	13%	2.88	0.64

Table 2: Benefits of business improvement

Benefits	(1)	(2)	(3)	(4)	Mean	SD
2.1 Reduce cost of implementing ECC	6%	38%	44%	12%	2.61	0.78
2.2 Reduce number and scale of disputes	6%	35%	50%	9%	2.62	0.74
2.3 Quicker closing of final accounts	8%	24%	46%	22%	2.83	0.87

Table 1 shows the results of three benefits related to CCM's assistance to the quality of the change management process. They indicate a consensus on the benefits in helping with the process of contract change management. For benefits 1.1 and 1.2, around 90% of the users responded positively. The replies from the client group are 100% "Agree" or "Strongly Agree" on these two benefits. The support for workflow automation (benefit 1.3) is recognized by 78% of the users.

Table 2 are results on the business improvement benefits. Although for all three benefits in this category the majority of the respondents answered "Agree" or "Strongly Agree", the results are less than overwhelmingly conclusive. It shows that IT can only provide the potential for business improvement. To realize the potential, corresponding changes in process, people and culture are required. Furthermore, it also illustrates the difficult in quantifying the impact IT tools in construction projects.

Table 3: Benefits of risk management

Benefits	(1)	(2)	(3)	(4)	Mean	SD
3.1 Greater visibility of status of all incidents	1%	11%	63%	25%	3.11	0.63
3.2 Provides a complete and documented audit trail	1%	2%	51%	46%	3.41	0.61
3.3 Provides early warning notification of risk	0%	11%	57%	32%	3.21	0.63
3.4 Rapid resolution of disagreements	6%	45%	44%	5%	2.45	0.68
3.5 Quicker agreement of compensation events	8%	30%	59%	3%	2.57	0.67
3.6 Focuses effort on proactive management of early warnings	1%	16%	65%	18%	2.99	0.63
3.7 Improves compliance to ECC procedures and contract management requirements	1%	6%	63%	30%	3.21	0.61
3.8 Reduces risks of implementing ECC	4%	18%	63%	14%	2.88	0.69

Table 3 shows the survey results of benefits related to risk management. In this category, the results showed a very big variation. For benefit 3.2, the percentage of “Strongly Agree” and “Agree” answers is 97%. However, for benefit 3.4 this percentage is only 49%. This is one of the only two benefits in this survey, which received less than half positive responses. This negative feedback of 3.4 shows the limited role that tools such as CCM can play after a disagreement occurs. However, tools can help to prevent some disagreements from happening in the first place, as indicated by the result for benefit 3.5. Another contributory factor for the low score for 3.4 may be the wording of the question. Even if CCM can play a role in resolving disagreement, its impact would not necessarily lead to ‘rapid’ resolution. Nevertheless, the general positive responses for most of the benefits, especially related to the implementation of NEC/ECC (3.1, 3.3, 3.7, 3.8), show that CCM users value the system in reducing process related risks of managing NEC/ECC projects.

Good communication is essential for both avoiding unnecessary changes and managing necessary ones effectively. Up to 91% of the CCM users agree with the benefits of the system in supporting and recording all communications related to each change event (4.3 and 4.7 in Table 4). The greater transparency provided by the system, especially from client’s and senior manager’s perspectives (4.4 and 4.6), is also recognized. Furthermore, the system also provides a central repository for all documents related to management of contract changes. As a result, the majority of the users believe that CCM helps to improve the communication between all the parties (4.1).

Table 4: Benefits of communication

Benefits	(1)	(2)	(3)	(4)	Mean	SD
4.1 Improves communication between all parties	5%	21%	60%	14%	2.84	0.73
4.2 Documents are not lost or mislaid – leading to a reduction in authentication queries.	0%	7%	60%	33%	3.27	0.57
4.3 Provides e-mail notification for important actions	4%	10%	60%	26%	3.09	0.71
4.4 Facilitates monitoring of the project by senior management	1%	9%	74%	16%	3.05	0.55
4.5 Instant availability of latest adjusted contract (target) price	4%	12%	64%	20%	3.00	0.69
4.6 Visibility to the client about changes in the project (usually price)	1%	6%	73%	2%	3.11	0.55
4.7 Records communications through PMI, EW, CE, NCE etc., thus reduces risk of unknown change	0%	9%	62%	29%	3.20	0.58
4.8 Use of CCM database as a master document for decision making and checking project status	3%	29%	57%	11%	2.76	0.68
4.9 Awareness of cost issues by all parties	4%	25%	55%	16%	2.84	0.74

Table 5: Benefits of management information

Benefits	(1)	(2)	(3)	(4)	Mean	SD
5.1 Data gathered can be analysed during and after the contract	3%	6%	71%	20%	3.09	0.60
5.2 Recording of contract progress with date stamps for easy retrieval and analysis	1%	8%	71%	20%	3.09	0.57
5.3 Provides online contract performance information	1%	18%	66%	14%	2.93	0.62
5.4 Provides data export facilities for key performance trend management	3%	23%	71%	3%	2.74	0.56
5.5 Improved predictability of end costs and end dates	4%	36%	51%	9%	2.66	0.70

Similarly, the feedback on benefits of management information is largely very positive (Table 5). One exception is "5.5 Improved predictability of end costs and end dates". A sizable minority (40%) of users did not agree with this benefit statement. The reason for this will be investigated in the next phase of research.

Table 6: Benefits of efficiency

Benefits	(1)	(2)	(3)	(4)	Mean	SD
6.1 Simple, point and click operation of the entire process	1%	16%	68%	15%	2.97	0.60
6.2 Minimizes administrative and secretarial activities	5%	23%	53%	19%	2.86	0.78
6.3 Version and authorization control of documents, minimizes disagreements over facts	1%	23%	58%	18%	2.93	0.68
6.4 Reduces QS time and costs, as CE are agreed quickly	9%	46%	33%	12%	2.47	0.82
6.5 Reduces QS costs due to reduction in unresolved issues post completion	8%	32%	51%	9%	2.62	0.77
6.6 Reduces post project completion issues	6%	24%	54%	17%	2.82	0.78
6.7 Improves quality of quotation, build up information and related audit trail	9%	27%	48%	16%	2.71	0.85
6.8 Saves man hours in document creation, filing and searching	6%	17%	51%	26%	2.96	0.83
6.9 User friendly software – reduces induction timescales	8%	12%	68%	12%	2.83	0.73

Table 6 shows the survey results for efficiency benefits. For benefits of efficiency about the operation of CCM system itself (6.1, 6.9), the answers were very clear-cut and positive, with 83% and 80% positive responses. For benefits of efficiency about project management, the answers were more mixed (6.2, 6.4, 6.5 and 6.6). Indeed, for "6.4 Reduces QS (Quantity Surveyor) time and costs, as CE agree quickly", over half (55%) of the respondents did not agree.

Table 7: Benefits of collaboration/partnering

Benefits	(1)	(2)	(3)	(4)	Mean	SD
7.1 Provides access to process operation and status information by all parties, any time, any place	0%	3%	75%	23%	3.20	0.46
7.2 Assures document version control through a secure audit trail	0%	6%	70%	23%	3.17	0.52
7.3 Facilitates collaborative decision making	1%	26%	63%	10%	2.82	0.62
7.4 Highlights next action which cannot be ignored or forgotten	0%	10%	66%	24%	3.14	0.57

Table 8: Benefits of traceability

Benefits	(1)	(2)	(3)	(4)	Mean	SD
8.1 Archives of key documents for analysis at any time	1%	8%	66%	25%	3.15	0.60
8.2 Date stamps all key operations	0%	1%	65%	34%	3.33	0.50

Collaboration and partnering underlie the core principle of NEC/ECC. CCM is designed to support this principle. The responses to the survey in this regard, shown in Table 7, confirmed that CCM benefits the promotion of collaboration between project partners. The positive answers for three out of four benefits in this categories are over 90%.

The main function of CCM is to support the key processes of NEC/ECC with regards to contract change management. The system keeps a record of the whole decision making process, which can be easily reviewed at a later stage. It is therefore not surprising to find that benefits of traceability received the highest rating (Table 8).

The ranking order of the categories of benefits was analysed according to the average percentage of positive replies (“Agree” and “Strong agree”). Traceability tops the list with 95%. It is followed by collaboration/partnering (89%), process improvement (86%), communication (84%), management information (79%), efficiency (70%) and finally business improvement (61%).

The rating for each benefit in Tables 1–8 is based on respondents’ assessment of that benefit independently. It is an indication of how well CCM helped to achieve that particular benefit. However, it does not imply the degree of importance of that aspect. In order to find out what are most important from the users point of view, respondents were asked to list top five benefits in an order of importance. During analysis, a weighing factor was assigned to different score, 100 to first benefit, 95 to second, 90 to third, 85 to fourth, and 80 to fifth. Then, the accumulative score is calculated for each benefit and a ranking is decided based on the final score. The benefit with the highest score ranks first, next highest score ranks second, and so on. The result, based on ranking from all respondents, is shown in column 2 of Table 9. The same analysis was also done for different groups of respondents separately. The results are shown in columns 3–5 of Table 9. It is interesting to note the difference in the ranking by different groups. For example, “3.7 Improves compliance to NEC/ECC procedures and contract management requirements” was ranked top by all respondents as a whole group. It was ranked top by clients and consultants in the organization category and by director/commercial managers and designer/engineers in the role category. However, it was only ranked fourth by contractors (in organization category) and seventh by project manager/contractor managers (in the role category). “1.2 Rigorous process for management of change” was ranked third overall, but did not even make the top 10 in the contractor’s ranking.

Table 9: Ranking of top 10 benefits

	Ranking by all	Ranking by clients	Ranking by contractors	Ranking by consultants	Ranking by PM/CM	Ranking by director/commercial managers	Ranking by designers/engineers
3.7 Improves compliance to ECC procedures and contract management requirements	1	1	4	1	7	1	1
3.2 Provides a complete and documented audit trail	2	4	7	2	1	-	2
1.2 Rigorous process for management of change	3	3	-	4	3	7	5
4.7 Records communications through PMI, EW, CE, NCE etc., thus reduces risk of unknown change	4	-	-	6	6	-	3
2.3 Quicker closing of final accounts	5	6	-	10	4	-	6
7.4 Highlights next action which cannot be ignored or forgotten	6	-	1	-	2	6	-
3.6 Focuses effort on proactive management of early warnings	7	-	-	5	5	-	-
7.1 Provides access to process operation and status information by all parties, any time, any place	8	-	-	3	8	-	7
3.3 Provides early warning notification of risk	9	-	2		-	2	-
3.1 Greater visibility of status of all incidents	10	-	3	10	-	8	8

Table 10: Estimations of financial value of CCM's benefits

Value of benefits (£)	**No of replies**
<5,000	6
5,000–10,000	3
10,000–50,000	4
50,000–100,000	4
>100,000	2
Average: £74,474	Total: 19

Risk management is clearly regarded as the most important issue. Five of the top ten benefits in Table 9 are related to risk management. When users were asked to identify top five benefits, they were also asked to indicate whether each identified benefit is related to "Reduction of Risk", "Reduction of Cost", or "Reduction of both Risk and Cost": 43% of the identified top benefits are regarded as related to "Reduction of Risk", 15% are related to "Reduction of Cost", and 43% are related to "Reduction of both Risk and Cost". Because some users ticked more than one box, the total percentage is over 100%.

The survey asked CCM users to quantify, if possible, the value of the benefits arising from using the system in their projects; 19 out of 85 respondents answered this question. The results are shown in Table 10.

It is widely acknowledged that the benefits of an IT system are often difficult to quantify in monetary terms. Any real savings are dependent on many factors, such as size of the project, competence of the project team, external context, etc. The IT system can only play a part, sometimes maybe an important part, in delivering business benefits. The figures in Table 10 are respondents' subjective estimates. The background contexts need to be investigated in detail before solid conclusions can be made.

Finally, 84% of users of the survey regarded CCM as a 'Good' or 'Excellent' system; and 92% of the users are happy with the quality of service by the service provider.

CONCLUSIONS

The questionnaire survey results were previously reported in an interim research report (Sun 2006). New in-depth analyses have been presented in this paper.

The results of the CCM user survey have proved users' appreciation of the benefits that the system provides during contract change management process of NEC/ECC projects. Overall, the users' responses are very positive and consistent: 41 or 43 benefits received positive feedback with a mean score higher than the median value. The standard deviations for most mean scores are relatively small. Process supports, such as audit trail and communication records, received the highest percentage of positive replies. The answers to benefits related to cost saving and business improvement are more mixed. Although there is a degree of consensus on the benefits that the CCM system is providing, there are considerable differences between different organizations and roles on what the most important benefits are.

REFERENCES

Arain, F M and Pheng, L S (2005) The potential effects of variation orders on institutional building projects. *Facilities*, **23**(11), 496–510.

CIRIA (1996) *IT in Construction – quantifying the benefits*. Construction Industry Research and Information Association, report 160, CIRIA, London.

Construct IT (1998) *Measuring the benefits of IT innovation*, Construct IT Centre of Excellence, University of Salford, Salford.

Ibbs, C W (1997) Quantitative impacts of project change: size issue. *Journal of Construction Engineering and Management*, **123**(3), 308–11.

Li, H (1996) Towards quantitatively measuring the performance of construction IT systems, *Building Research and Information*, **24**(1), 379–82.

Love, P E D and Li, H (2000) Quantifying the causes and costs of rework in construction. *Construction Management and Economics*, **18**(4), 479–90.

Love, P E D, Irani, Z and Edward, D J (2005) Researching the investment of information technology in construction: an examination of evaluation practices. *Automation in Construction*, **14**, 569–82.

Marsh, L and Flanagan, R (2000) Measuring the costs and benefits of information technology in construction. *Engineering, Construction and Architecture Management*, **7**(4), 423–35.

Mitchell, B and Trebes, B (2005) *NEC: Managing Reality: Complete Set of Five Guides*. London: Thomas Telford Ltd.

Stewart, R and Mohamed, S (2003) Evaluating the value IT adds to the process of project information management in construction. *Automation in Construction*, **12**, 407–17.

Sun, M and Oza, T (2006), Interim research report: Collaboration support realises business process benefits for NEC/ECC projects, University of the West of England, Bristol, UK. Available online: www.built-environment.uwe.ac.uk/research/cprc/publications/CCM-nov2006.pdf

TECHNOLOGICAL READINESS FOR WIDESPREAD USE OF E-COMMERCE IN CONSTRUCTION

Ihab Ismail[1] and Vineet Kamat

Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, MI, USA

This paper discusses e-construction infrastructure, its definition, importance and status, and recommendations for its improvement. This paper builds on the current existing research in e-construction and offers recommendations for restructuring e-construction by focusing first on the infrastructure as the first building block. The paper will summarize the challenges in e-construction while focusing on providing a framework to overcome those challenges. The paper starts by defining the e-construction infrastructure, then presents an argument for why we should investigate e-construction infrastructure. It then proceeds to summarizing the status of e-construction infrastructure, and provides a framework for improvement. The e-construction infrastructure is interdisciplinary in nature; it involves business process, trading models, network hardware and software infrastructure, software interoperability standards, legal standards, and more. Therefore, an interdisciplinary approach is used in building or improving this infrastructure. The thesis of this paper is that the ultimate value that the industry can derive from e-construction will be reached when those disciplines and standards are aligned in an integrated e-construction infrastructure.

Keywords: contracting, information management, information technology, modelling, standardization.

INTRODUCTION

The successful execution of a project requires preplanning – a phase known in the architectural, engineering and construction (AEC) industry as preconstruction. This is well known and widely practiced in the construction industry (Anonymous 2005c). Contractors plan their projects before they bid or attempt to execute them. It is surprising then to see why the construction industry embarked on a long journey, one that was indeed needed, of IT investments with little or no pre-planning. The lure of first to market advantages, large volume of transactions, and prospects of high market share have sparked a rat race for investment in information Technology (IT) and electronic construction (e-construction). It has been estimated that US$2.5 billion was spent in capital investments by Application Service Providers creating Project Management and collaboration portals alone (Nitithamyong and Skibniewski 2004). It is naïve to expect that by investing in IT alone, the construction industry will adapt naturally to the new infrastructure and the business processes will change to accommodate the change. Dramatic improvement in industry performance requires equally dramatic changes to business processes and management practices, and, more importantly, a strong infrastructure to support these changes (Severance and Passino 2002). It comes as no surprise that the productivity for many AEC companies have been flat or declined over the past five years despite of all the IT investments completed in the same period (Anonymous 2005c)

[1] beta@umich.edu

This paper is part of ongoing research at the University of Michigan that aims at analysing the status of e-commerce in the construction industry, the e-commerce infrastructure, identifying impediments and challenges, and research solutions for the identified challenges. As the topic is multidisciplinary in nature, the research is also multidisciplinary covering knowledge in computer science, construction engineering and management, business, and legal aspects; it involves business process, trading models, network hardware and software infrastructure, software interoperability standards, legal standards, and more. To approach this multidisciplinary problem, a framework was identified for analysing and managing e-construction barriers and challenges. The research grouped the challenges under four focus areas: technological, risk management, managerial and organizational, and information liquidity. The thesis of this paper is that the ultimate value that the industry can derive from e-construction will be reached when those disciplines and standards are aligned in an integrated e-construction infrastructure.

This paper is the second in a series of papers discussing each of the focus areas. The first paper focused on legal risks analysis for e-construction (Ismail and Kamat 2005). The focus in this paper will be on discussing the e-construction infrastructure, its importance, status and recommendations for its improvement. This paper builds on the current existing research in e-construction and offers recommendations for restructuring e-construction by focusing first on the infrastructure as the first building block. The paper will summarize the challenges in e-construction while focusing on providing a framework to overcome those challenges. The paper starts by defining the e-construction infrastructure, then presents an argument for why we should investigate e-construction infrastructure. It then proceeds to summarizing the status of e-construction infrastructure, and provides a framework for improvement.

E-CONSTRUCTION INFRASTRUCTURE

The e-commerce infrastructure is defined here as the supporting capabilities for online trading between multiple companies which includes hardware, software, networks, online payment technologies, security and encryption technologies, online trading business models, and legal and regulatory framework. This can be broken down into the following four groups of components:

- Technology aspects. Hardware, software, networking protocols, encryption technology, online payment technology, etc.
- Business aspects. Business models (Business to Business (B2B), Business to Consumer (B2C), Consumer to Consumer (C2C)), Internet-enabled business processes, supply-chain integration capabilities, information liquidity, etc.
- Legal and regulatory aspects. Legal requirements for e-commerce, regulations for electronic trading, electronic signature act, etc.
- Information Liquidity and Knowledge Management. Level of information liquidity and common across-industry taxonomy are critical for deriving more value from e-commerce markets.

Users can often be included as the fifth category. One can argue that users are one of the most important supporting capabilities for online trading, and often is the case that they are one of the most important challenges as in the construction industry.

Figure 1 illustrates an e-construction marketplace technology infrastructure. It shows buyers and seller with different connection configuration (single computer access, multiple computer access, and multiple computers, multiple location networked access.) Buyers and sellers can connect to the e-construction marketplace through the Internet. The Internet connections could be established by connecting to the Internet Service Provider (ISP) through dial-up, digital subscriber line (DSLs), T1, T4 or other link types. The e-construction configuration (e-construction marketplace versus single point buyer B2B e-commerce, single point seller B2B or B2C e-commerce) represents the business aspect. The third aspect is represented through the legal and regulatory framework within which these online trading activities operate, and the fourth aspect represents that market information that flows between different network nodes.

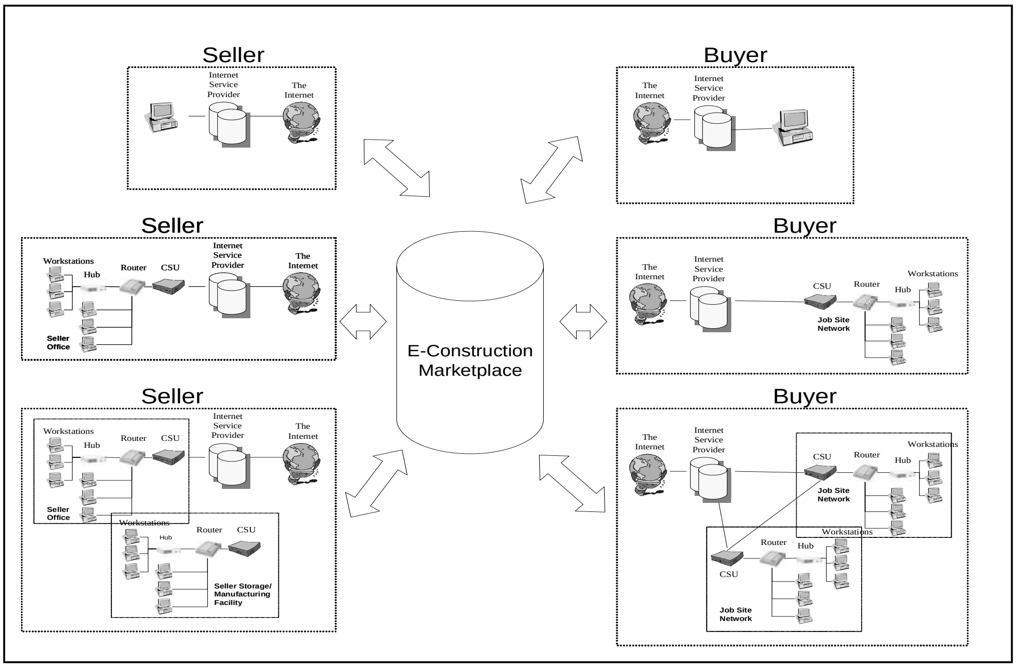


Figure 1: E-construction marketplace infrastructure model

WHY INVESTIGATE E-CONSTRUCTION INFRASTRUCTURE

The value of e-commerce increases exponentially in proportion to the number of users. This is stated in the literature in different variations. Metcalfe's law states that "the value of a network increases by the square of the number of people or things connected to it", and Kelly's law of networks states that "in online exchanges, where multiple buyers and multiple sellers come together in a virtual trading space, the potential value of a neutral B2B exchange is thus nn, where n is the number of users connected to that exchange" (Sculley and Woods 2001). This is better explained by using e-bay as an example. E-bay is a Customer-to-Customer (C2C) electronic marketplace which creates many market efficiencies such as easier search tools, better pricing mechanisms derived through auctioning, and an online reputation tracking system; however, the core value of e-bay is its ability to connect more buyers to more sellers than in conventional markets. Gaining critical mass in a market segment is key for success in order to deliver value to participants. Figure 2 shows that the growth of Gross Merchandise Sales on e-bay mimics closely the growth pattern of the number of e-bay users and that both are of exponential nature (source numbers are taken from E-bay Annual Report) (E-Bay 2003).

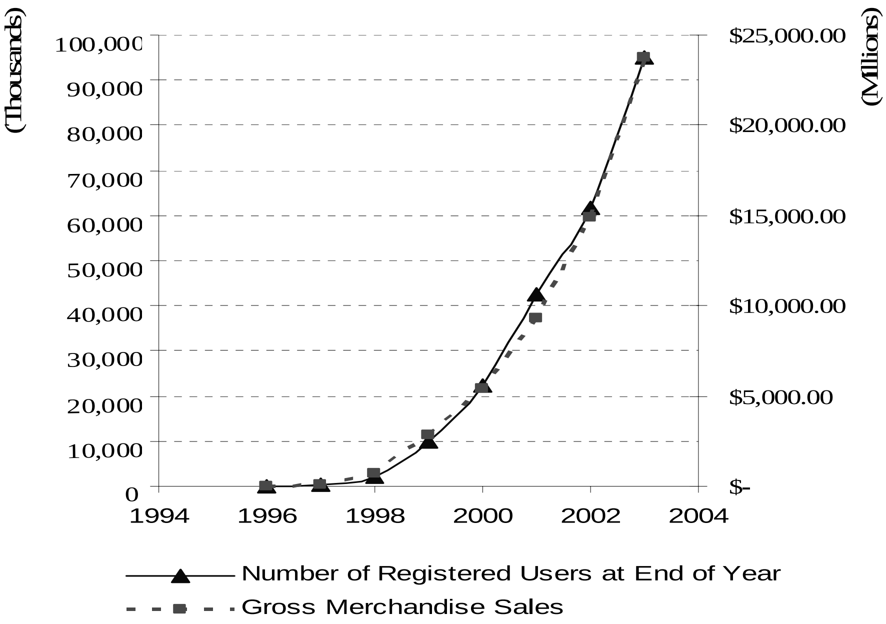


Figure 2: Growth of E-Bay users and gross merchandise sales

Kelly's law applies to e-construction in a similar manner. E-construction is similarly undergoing a process of exponential growth caused by a rapid evolution of the value of e-construction coupled with decreasing barriers of entry. This process will drive more members of the AEC industry to join the e-commerce network putting more pressure on the current e-construction infrastructure. It is important then to analyse what is needed to strengthen this infrastructure in the next phase and to allow for higher returns on e-construction investments.

This trend has been identified in the literature for e-construction. The tipping point estimated between 2004 and 2005 (Nitithamyong and Skibniewski 2004; Unger 2002) and occurs when the online e-construction solutions mature enough to stabilize and reduce the cost of participation to be justifiable for small and medium enterprises. Additionally, a survey conducted by *Engineering News Records* (ENR) estimates the number of AEC firms using e-construction tools to double every six months (Nitithamyong and Skibniewski 2004).

SUMMARY AND STATUS OF E-CONSTRUCTION CHALLENGES

The construction industry in the US in particular, and in many other developed countries in general, recognized the successes and challenges of e-construction. There are a magnitude of reports in the literature about e-construction; many about the challenges of e-construction. Perhaps the most comprehensive is the Construction Industry Institute research on e-construction (Veeramani *et al*. 2002). There are many additional resources that discuss web based project management and survey user view points (Nitithamyong and Skibniewski 2004; Mohamed and Stewart 2003; Stewart and Mohamed 2004; Love *et al*. 2004). The following is a summary of the key challenges facing e-construction grouped and organized within the framework developed under this research. The summary is adapted from the literature (Nitithamyong and Skibniewski 2004; Veeramani *et al*. 2002; Gallaher *et al*. 2004) and expanded upon based on the current research findings.

Technological challenges

Perhaps the one area that is investigated heavily in e-construction relates to the technology (Nitithamyong and Skibniewski 2004). There are several challenges related to the technological aspects of the e-construction infrastructure. These are: interoperability, security, in-adequate software, connectivity, and reliability.

The problem of interoperability arises when there is a many-to-many trading relationship. When each supplier is dealing with few buyers, or each buyer is dealing with few suppliers, preset exchange protocols can be established alleviating interoperability issues. Interoperability is a major concern in all aspects of e-construction. The cost of interoperability is one of the major challenges to wide implementation of e-construction (Veeramani et al. 2002). Suppliers are faced with the dilemma of having to adapt to all their client online trading needs while still catering to their own internal standards (Gallaher *et al*. 2004). Several groups, such as International Alliance for Interoperability (IAI) (Anonymous 2005b) and FIATECH – an industry led, collaborative, not-for-profit R&D Consortium (Anonymous) – are currently working on solutions for this issue.

Security is also a major concern for e-construction applications (Nitithamyong and Skibniewski 2004; Veeramani *et al*. 2002; Alshawi and Ingirige 2003; Berning 2003). So far, most e-construction applications are using user passwords as the single attribute authentication system. As the industry moves to exchanging more important information online, the single attribute system will not be adequate. One can also establish that it is not adequate for the current use of project management and collaboration, but most certainly, it is less adequate for legally enforceable electronic contracts or documents with legal consequences.

The fragmentation of the software features and lack of enterprise-wide solutions is yet another one of the key reasons for the industry's inability to fully utilize the e-construction environment to boost its productivity (Veeramani *et al*. 2002; Alshawi and Ingirige 2003; Berning 2003). Several surveys have indicated that users are looking forward for an enterprise-wide solution instead of the stand-alone software for each business task (e.g. scheduling, estimating and collaboration) that is currently in use (Veeramani *et al*. 2002; Anonymous 2005a).

Connectivity and reliability are closely related although different challenges. Connectivity relates to the number of business entities that are connected to a network. As illustrated earlier in this paper, the network value increases rapidly with the increase in the number of connected users. The fact that many construction sites are located miles away from the nearest connection point for a T1, DSL or broadband connection could present a challenge (Fischbach 2002).

A recent report stressed the increasing costs of maintaining network availability with the added impact of voice data additions, weaknesses in the U.S. power grid, and increased equipment density (Anonymous 2004). The report also indicated that availability goals are increasing for all network providers (Anonymous 2004). It is important to note that reliability for online e-construction application depends on many factors other than establishing redundancy and reliability at the application server side. The network is usually as reliable as its weakest link is. If contractors do not utilize an Uninterrupted Power Supplies (UPS) system, they risk connection failures because of power outages even though they subscribe to a network provider than have redundant UPSs system in place on their server side. Power failures are only but one cause of network failure. Human error has been identified as the highest of any factors causing network failure, followed by viruses, hardware failure, software failure and power failure, consecutively (Anonymous 2004). Reliability will become more important as e-construction crosses the casual exchange of documents online, to the more time-sensitive e-procurement arena. Contractors will want to ensure that their network will not fail when they are in the process of submitting their time-sensitive bids online. Bid recipients on the other side will also want to ensure their systems can handle the high-traffic required at bid submission times (Berning 2003). Reliability can also surface in different forms than the previously discussed: reliability of the service provider or online market-maker to remain in business. BuildNet is an example for this challenge. BuildNet filed for bankruptcy and their customers had to switch to other systems when their contracts were bough by BuildNet's competitors as part of the bankruptcy settlement (Berning 2003).

Legal challenges

The legal challenges are the least investigated as it relates to e-construction. Legal issues are extremely relevant and important to any e-construction effort. The size and complexity of transactions present the key difference between e-construction and buying a book at Amazon.com, for example. Legal challenges was investigated in more detail in this research and published in another paper (Ismail and Kamat 2005). The key legal issues are agency, jurisdiction, contract formation, validity and errors, authentication, attribution and non-repudiation, and privacy concerns.

The most difficult legal challenge in e-construction is posed by intelligent software agents. Software agents are computer programs capable of learning and taking decisions on behalf of their owners (Dzeng and Lin 2004; Ren and Anumba 2004). They take decisions themselves instead of supporting users in making decisions (Ren and Anumba 2004; Schoop *et al*. 2003). Several software agents are developed, or currently in development, that target the construction industry (Dzeng and Lin 2004; Ren and Anumba 2004; Anumba *et al*. 2003; Tah). Intelligent agents pose serious legal challenges to the current legal system primarily in the area of contracting and agency laws. The basic question is whether intelligent agents could have a separate legal personality from their owner or not? The law will not necessarily accept the capability of agents to take actions on behalf of owners as legal consent from the owners to bind them contractually (Bain and Subirana 2003).

Jurisdiction issues pose the next challenge to e-construction. Electronic contracts have no geographical boundaries. Laws and regulations, in contrast, do have geographical boundaries. This basic decision of which court has jurisdiction over a dispute is challenged by these contradictions. This challenge often exists in areas like intellectual property rights. Determining jurisdiction for intellectual property rights is important for distribution of drawings and project documents online in e-procurement systems.

A contract is a promise for a promise (Fuller and Eisenberg 2001). The promises are usually exchanged as an offer and acceptance of the offer. In e-construction transaction, however, it may not be easy to distinguish the offeror from the offeree. This threatens the essence of the contract for a contract is not formed unless the offer is accepted by the oferee.

Authentication, attribution and non-repudiation are yet another set of concerns for e-construction. Attributing an electronic message or agreement to an e-contract to the person who purports to send is critical to the success of e-procurement initiatives. The Uniform Electronic Transaction Act (UETA) addresses this issue by allowing electronic signatures in lieu of signatures; however, the level of authentication depends on the type of security used to collect the "electronic signature" (Pacini *et al*. 2002; Belgum 1999; Moreau 1999; Thelen Reid & Priest LLP 1999).

Privacy is also a major concern in e-construction. Contractors and owners bidding on e-construction marketplaces disclose information about themselves and their bids. E-commerce marketplaces and portals may derive value from collecting this information (Millard 2000; Crichard 2003). Additionally, an owner may be in violation of privacy laws if hackers gain access to confidential bidding information of contractors through their servers.

There is another group of legal risks that are not based on conflicts of law and can be addressed at the contract formation stage for each project. Data ownership after project completion, insurance risks for damages due to electronic system failures, and who bears the responsibility for loss of data or risk of hackers in construction projects using electronic project management systems are few examples in this category.

Managerial and organizational challenges

Managerial and organizational challenges are much less emphasized in the literature than the technological challenges. This is contradicting to the fact that almost all industry surveys recognized the importance of those issues (Nitithamyong and Skibniewski 2004). Managerial and organizational challenges identified in the past can be summarized as follows:

- Establishing Return on Investment (ROI) is difficult for many companies. This in turn creates difficulty in making business case to justify investments in e-construction (Nitithamyong and Skibniewski 2004; Veeramani *et al*. 2002).
- General strong cultural resistance encountered by all industry sectors. Resistance to change (Veeramani *et al*. 2002).
- Lack of comprehensive software with features addressing all participants. Current software focus on one entity (Contractor, Owner, or Architect) (Nitithamyong and Skibniewski 2004).

Equal in importance, if not more important, than the listed items are the electronic business models used in e-construction. To evaluate why many e-procurement business models, as an example, pose risks to the construction industry, we must first establish the difference between the types of procurement approaches. Procurement contracts can be negotiated or non-negotiated (pre-established). Also, procurement decisions can be based on long-term value maximizing strategic objectives, or short-term single transaction value maximizing objectives. E-commerce business models are often more efficient for one procurement type than the other. Non-negotiated, short-term single transactions are the least complex types of e-commerce transactions. Often, the one deciding factors for this types of transactions is price. Efficiencies could be gained in a buy-side e-procurement model (e.g. Ariba, Oracle, SAP), seller-side e-procurement model (e.g. Amazon), or an exchange and auction model (e.g. e-bay). On the other hand, negotiated, relation-building transactions are the most complex type of transactions. In this type of transactions, delivery terms, warranty, specifications and schedules can be all negotiated in addition to price. The additional complexity warrants additional precautions if the same business model used in less complex transactions is utilized here. Identity and authentication requirements must be stricter and legally binding; pre-qualifications and reputation building protocols also become more important. Even with more precautions and higher system standards, the business model itself could not be suitable to derive enough efficiency to make the model feasible for such transactions. For example, some claim that reverse auctions are not beneficial for long-term market efficiency (Berning 2003). The business model of reverse auctions work against the market dynamics long-established in the construction industry. The probability that one bidder may bid at a loss in the hopes of making more profit on changes increases the chances of project claims.

Information liquidity and knowledge management challenges

To discuss information liquidity and knowledge management and their importance in e-construction, a distinction between data, information and knowledge must be first established. Data are “facts and figures that are meaningful in some way”; information is “data that has been organized for a particular purpose” (Blair 2002). Knowledge, on the other hand, is more difficult to define; however, it could be described as information intertwined with the intellectual ability to put this information to use (Blair 2002). Knowledge can be either tacit or explicit (Woo *et al*. 2004). Tacit knowledge is the knowledge that experts posses; it is highly context based. Tacit knowledge is further divided into two distinct types: knowledge that can be expressed in logical forms but has not been expressed yet and knowledge that is not expressible (Blair 2002).

Information liquidity is analogous to financial liquidity. Information has more value when it is more readily accessible or, in other words, when it is "liquid". Information liquidity is defined as "the ability to acquire, understand and make use of information when it is needed, where it is needed, in an appropriate context of content and meaning" (Teflian 1999). Information liquidity is critical to electronic transactions. The value of companies in an all-connected world is shifting more towards its ability to harness the power of information, and growing its experience and knowledge base (Teflian 1999).

Information liquidity and knowledge management are particularly challenging for e-construction. Because of the uniqueness of each construction project, much of the knowledge in the industry is tacit knowledge (Woo *et al*. 2004). Tacit knowledge is the least liquid type of knowledge and the most difficult to transform into logical statement and information. This poses a great challenge to e-construction since the value of the network depends greatly on the amount of accurate information that flows in the network.

Integrated e-construction infrastructure framework

It has been shown that e-construction infrastructure is interdisciplinary. E-construction infrastructure is the conglomeration of technological, legal, management and organization, and information infrastructures. Figure 3 illustrates what this paper proposes to be an integrated e-construction infrastructure. The coordination of all these disciplines is a key component for the success of e-construction improvement efforts. The lack of coordination between these components may change the dynamics of the industry or create unequal distribution of risks.

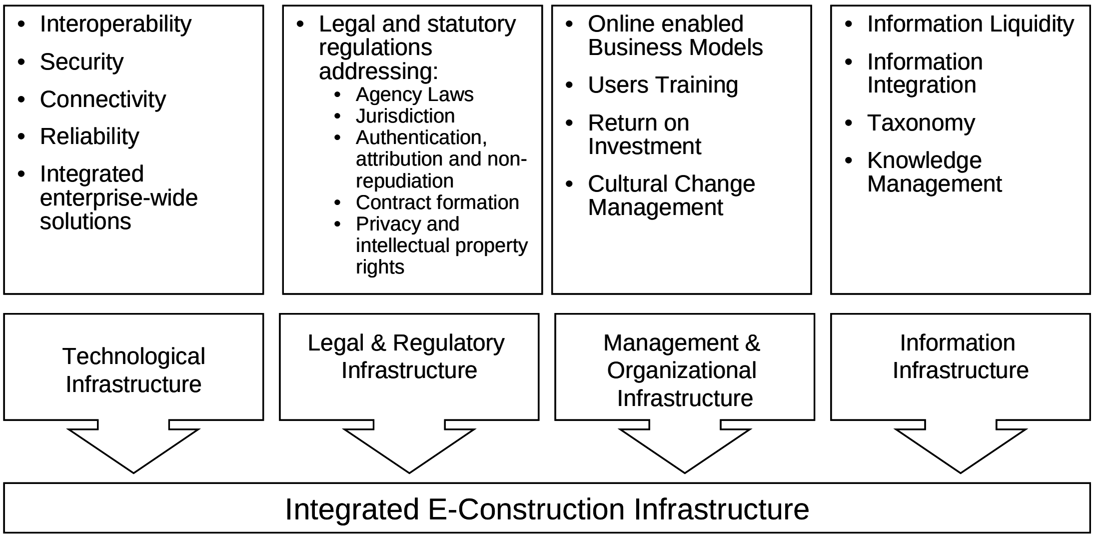


Figure 3: Integrated e-construction infrastructure

One such example that is changing the dynamic of the industry by virtue of changing its risk allocation mechanisms is the conflict between the pre-existing legal doctrine of promissory estoppel and the risk "standard" agreement with software providers. For a contract to be enforceable it must have consideration (Fuller and Eisenberg 2001). For example, a contractor promises not to sell its used equipment that it owns until certain date so that another contractor (potential buyer) arranges its finance, but sell it before that date. The contractor's promise in not enforceable because it lacks consideration. If however, the contractor accepts a down payment, or a certain sum of money in consideration for the promise, the promise is binding and enforceable in court. Promissory estoppel, sometimes referred to as detrimental reliance, is an exception to this rule. Promissory estoppel occurs when "a promise which the promisor should reasonably expect to induce action or forbearance of a definite and substantial character on the part of the promise and which does induce such action nor forbearance is binding if injustice can be avoided only be enforcement of the promise" (Fuller and Eisenberg 2001). Promissory estoppel has been generally utilized in Construction Law to bar bidders from retracting their bids if general contractors depended on their bid price when submitting their bid to the owner. This was justifiable on the basis that contractors had relied on subcontractors' prices, and subcontractors should be responsible for their price since they know when they submit it that contractors will rely on it for their pricing. The general view was that subcontractors have given a promise to provide accurate price in exchange for an opportunity to win the project.

Recently, the expanded use of e-construction required an increased use and dependency on software. Often times the owner or general contractor dictate that they will only receive bids electronically and some times contracts dictate the use of certain project management and collaboration software for all entities working on a given project. This standardization solves some of the interoperability challenges in a given project and improves efficiency in that respect; however, if uncoordinated with the other dimension of the e-construction infrastructure it disrupt the dynamics of the industry.

The case of Mortenson Co., Inc. v. Timberline Software Corp. is a representative example. Mortenson, a general construction contract, purchased licensed estimating software from Timberline. The contractor used the software to estimate its construction costs and prepare bids. It specifically used the software to prepare for a bid that was accepted and then realized that the bid was $1.95 million less than it should have been. It was later discovered that there was a bug in the software that Timberline discovered earlier but though to be un-important. Mortenson sued Timberline to recover $1.95 million in damages. The court held that the shrink-wrap on the software cover included an agreement that limited the liability of the software company to the purchase price of the software. It expressly waived the right to recover consequential damages. The court also held that the licence agreement on the shrink-wrap instructed the purchaser to return the software for a complete refund if they don't agree with the terms. By opening the software pouch, the contractor has accepted a valid way of contracting with a software company and has limited its recovery to the price of the software (Hennigh 2000). However, on the other hand, the court has held the contractor responsible for its submitted price to the owner based on the doctrine of promissory estoppel and on the basis that the owner had relied on the contractor's price.

On a micro-scale, this case illustrates the importance of analysing the risks of using software under a strict licence provisions. Although companies may try to negotiate the terms of the licence agreement with the software company, it is highly unlikely that it will be changed. Bigger contractor may have more leverage negotiating such agreements if they are considering buying a national licensee. Smaller contractors and subcontractors have no leverage in negotiating better terms. On a macro-scale, however, the standardization of software licences agreements to waive the responsibility of the software company of its liability for programming mistakes is in contradiction to the increasing demand from owners to use the same software without agreeing to take part of the added liability to contractors. The same contradiction could be though of if owners require all bidders to use an online marketplace, and the marketplace has established through a click-through agreement that they have the right to collect and use information about participating contractors. Contractors are left with no choice other than not bidding and potentially loosing up project opportunities and/or their business, or give up their privacy rights. This right of only accepting bids using by electronic means or online has even been granted to agencies bidding for public work (Berning 2003).

Another contradiction occurs between the technological aspects of e-construction and the legal aspects. One of the complaints by online project management system users is the large amount of emails they receive everyday. This problem has been exaggerated by the amount of spam mail that is received in the same inbox. Sifting through everyday to determine important email from spam email is a time consuming task that reduces the efficiency of the system. The improvement in technology offered a new solution for this problem in the form of spam filters. The lack of coordination between the use of spam filters and the other dimensions of the e-construction infrastructure; namely the legal aspects, have caused another contradiction. What happens if an important "legal" document is mistakenly filtered as spam? Who is responsible for this mistake if the spam filter is provided as part of the services included with the online project management software? Should we assume that the contractor has the responsibility to search in the filtered emails, provided, they have access to them? If so, then there is no benefit added by using the spam filter. Or should be assume that the owner must check that the contractor received every document that they sent online? If so, then the owner will either have to duplicate everything in paper and send it to the contractor or call to check if online items have been received on the other side, therefore, loosing the benefit of collaboration.

Development of the information infrastructure may also contradict with the development of the technological infrastructure and interoperability requirements. To increase information liquidity some standardization has to happen across the industry. For example, a common taxonomy, and a common product code must be established. On the other hand, interoperability requirements need some standardization in terms of vocabulary and product code structure. Those requirements must be coordinated together or else standardization efforts will fail on both sides.

Many other examples can be cited for the importance of an integrated, coordinated e-construction infrastructure: security requirements must be coordinated with legal requirements; business models and software requirements; and business models and legal regulations.

CONCLUSIONS

E-construction is poised for widespread application in the construction industry. It is being embraced by more AEC firms everyday. The expected exponential increase in the users is matched with an increase in the amount of investment. Users and the industry will ultimately be looking for e-construction to payoff for this investment. This payoff will be derived in terms of added value to the construction operations and more efficiency. To be able to gain this efficiency and value, the infrastructure upon which e-construction is built must be strong and well coordinated. This has not been the case in the past, and is not the case now. The integrated e-construction infrastructure framework is ultimately needed to secure this strong foundation and therefore the future of e-construction. It is also needed to gain the expected benefits and increase the efficiency of contractors and subcontractors.

CONTRIBUTIONS AND FUTURE RESEARCH

Technological challenges have been the sole focus of improvement when it comes to e-construction (Nitithamyong and Skibniewski 2004). This comes as no surprise since it is a topic of highest familiarity for an industry that is accustomed to technical issues and their solutions. The other three groups of challenges have gained little or no attention whosoever. More important, the coordination between the developments of solutions in all four groups does not exist. As the changes are multifaceted and interdisciplinary in nature, the solution must be interdisciplinary. This gap in the literature is acknowledged and identified in this paper, and is collectively addressed in the current research.

A framework for identifying and categorizing e-construction challenges is presented, and an integrated e-construction infrastructure framework is discussed. The conflicts between unbalanced improvements in one aspect of the framework and the others are also discussed. Feature research is needed to identify different methods to coordinate the work of four aspects of the e-construction infrastructure and create linkage between them.

ACKNOWLEDGMENTS

The presented work has been partially supported by the National Science Foundation (NSF) through grant CMS-0408538. The authors gratefully acknowledge NSF's support. Any opinions, findings, conclusions and recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the NSF.

REFERENCES

AEC Workers Want More Flexibility From Project Management Software. (2005) Available online: http://ecmweb.com/market/electric_aec_workers_flexibility/ (accessed 13 March 2005).

Alshawi, M and Ingirige, B (2003) Web-enabled project management: an emerging paradigm in construction. *Autom.Constr.*, **12**(4), 349–64.

Anumba, C J, Ren, Z, Thorpe, A, Ugwu, O O and Newnham, L (2003) Negotiation within a multi-agent system for the collaborative design of light industrial buildings. *Adv.Eng.Software*, **34**(7), 389–401.

Bain, M and Subirana, B (2003) Legalising autonomous shopping agent processes. *Computer Law & Security Report*, **19**(5), 375–87.

Blair, D C (2002) Knowledge Management: Hype, Hope, or Help? *Journal of the American Society for Information Science and Technology*, **53**(12), 1019–28.

California is First State in Nation to Adopt Electronic Contracting Law (1999) Available online: http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/Nov_18_1999/nov_18_1999.html (accessed 5 October 2004).

Contractor Denied Recovery for $1.95 Million Bidding Error Caused by Allegedly Defective Software (2000) Available online: http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/Sept_18_2000/defective_software.htm (accessed 20 September 2004).

Crichard, M (2003) Privacy and electronic communications. *Computer Law & Security Report*, **19**(4), 299–303.

Dzeng, R and Lin, Y (2004) Intelligent agents for supporting construction procurement negotiation. *Expert Syst.Appl.*, **27**(1), 107–19.

E-Bay: 2003 Annual Report (2003) Available online: http://investor.ebay.com/annual.cfm (accessed 8 March 2005).

E-Commerce and the Construction Industry: User Viewpoints, New Concerns, Legal Updates on Project Web Sites, Online Bidding and Web-Based Purchasing (2003) Available online: http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/Dec_22_2003/e_commerce.htm (accessed 1 November 2004).

Fuller, L L and Eisenberg, M A (2001) *Basic Contract Law.* St. Paul, MN: West Group.

Gallaher, M P, O'Connor, A C, Dettbarn, J L and Gilday, L T (2004) *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*. *Rep. No. NIST GCR 04-867.* Gaithersburg, MD: National Institute of Standards and Technology.

http://www.fiatech.org/

Information Liquidity (1999) Available online: http://www.eyefortransport.com/archive/time03.pdf (accessed 19 September 2004).

International Alliance for Interoperability (IAI) (2005) Available online: http://www.iai-na.org/ (accessed 9 March 2005).

Ismail, I A and Kamat, V R (2005) Legal Risk Analysis, Modelling, and Programming for E-Commerce in Construction. *Construction Research Congress*.

Legal Issues in Contracting on the Internet (1999) Available online: http://www.constructionweblinks.com/Resources/Industry_Reports__Newsletters/June_1999/june_1999.html (accessed 28 October 2004).

Love, P E D, Irani, Z and Edwards, D J (2004) Industry-centric benchmarking of information technology benefits, costs and risks for small-to-medium sized enterprises in construction. *Autom.Constr.,* **13**(4), 507–24.

Millard, C (2000) Four Key Challenges for Internet and E-Commerce Lawyers. *Computer Law & Security Report*, **16**(2), 75–7

Mohamed, S and Stewart, R A (2003) An empirical investigation of users' perceptions of web-based communication on a construction project. *Autom.Constr.,* **12**(1), 43–3.

Moreau, T. (1999) The emergence of a legal framework for electronic transactions. *Comput.Secur.,* **18**(5), 423–8.

M.A. MORTENSON COMPANY, INC., Petitioner, v. **TIMBERLINE SOFTWARE** CORPORATION and SOFTWORKS DATA SYSTEMS, INC., Respondents.. 140 Wn.2d 568; 998 P.2d 305; 2000 Wash. LEXIS 287; CCH Prod. Liab. Rep. P15,893; 41 U.C.C. Rep. Serv. 2d (Callaghan) 357. SUPREME COURT OF WASHINGTON.

Nitithamyong, P and Skibniewski, M J (2004) Web-based construction project management systems: how to make them successful? *Autom.Constr.,* **13**(4), 491–506.

Pacini, C, Andrews, C and Hillison, W (2002) To agree or not to agree: Legal issues in online contracting. *Bus.Horiz.,* **45**(1), 43–52.

Productivity Down, Pre-Planning Up for Many Construction Companies." (2005) http://ecmweb.com/mag/electric_productivity_down_preplanning/ (accessed 13 March 2005).

Ren, Z and Anumba, C J (2004) Multi-agent systems in construction-state of the art and prospects. *Autom.Constr.,* **13**(3), 421–34.

Schoop, M, Jertila, A and List, T (2003) Negoisst: a negotiation support system for electronic business-to-business negotiations in e-commerce. *Data Knowl.Eng.,* **47**(3), 371–401.

Sculley, B A and Woods, W W A (2001) *B2B Exchanges: The Killer Application in the Business-to-Business Internt Revolution.* New York: HarperCollins Publishers, Inc.

Severance, D G and Passino, J (2002) *Making I/T Work.* San Francisco: Jossey-Bass.

Stewart, R A and Mohamed, S (2004) Evaluating web-based project information management in construction: capturing the long-term value creation process. *Autom.Constr.*, **13**(4), 469–79.

Tah, J H M (in press) Towards an agent-based construction supply network modelling and simulation platform. *Autom.Constr.*, in press.

Team Collaborates Online to Manage Airport Renovation (2002) Available online: http://ecmweb.com/mag/electric_team_collaborates_online/index.html (accessed 13 March 2005).

The 2004 Liebert Availability Report (2004) Available online: http://www.liebert.com/support/whitepapers/documents/avail_surv.asp (accessed 13 March 2005).

The trend toward an internet-based communication standard in the A/E/C industry (2002) Available online: http://www.constructware.com/common/downloads/standardization_white_paper.pdf (accessed 9 March 2005).

Veeramani, R, Russel, J S, Chan, C, Cusick, N, Mahle, M M and Roo, B V (2002) State-of-Practice of E-Commerce Application in the Construction Industry. *Rep. No. 180-11.* Austin, TX: Construction Industry Institute,.

Woo, J, Clayton, M J, Johnson, R E, Flores, B E and Ellis, C (2004) Dynamic Knowledge Map: reusing experts' tacit knowledge in the AEC industry. *Autom.Constr.*, **13**(2), 203–7.

VISUAL REPRESENTATION OF CONSTRUCTION PROGRESS MONITORING METRICS ON TIME-LAPSE PHOTOGRAPHS

Mani Golparvar Fard,[1] Aravind Sridharan,[2] SangHyun Lee[3] and Feniosky Peña-Mora[4]

[1,2,4]*Construction Management Group, Department of Civil and Environmental Engineering, University of Illinois, Urbana-Champaign, 205 N. Mathews Ave., Urbana, IL 61801, USA*
[3] *Department of Civil and Environmental Engineering, University of Alberta, 3-133, Markin/CNRL Natural Resources Engineering Facility Edmonton, Alberta, T6G 2W2, Canada*

A low cost progress data collection technique for construction projects using time-lapse photography or real-time videotaping can provide a wealth of spatial and temporal information for progress data collection. The benefits of using photographs would be maximized if the progress deviations between planned and actual (as-built) performance are visually shown on these photographs. The importance of such visual representation of construction progress is well understood when the participation of diverse parties with different levels of expertise (from owners to subcontractors) is considered. Current formats of monitoring reports (e.g. textual progress reports, progress graphs or charts) may not properly and quickly communicate progress situations and would make understanding of the progress situation difficult. Current methods of monitoring require manual data collection and extensive data extraction from construction documents making progress monitoring a time-consuming process and distracts managers from the important task of decision making. As an effort to address this issue, a visual representation of construction progress is proposed that aims to picture the progress situation on time-lapse photographs (representing actual progress), superimpose the planned progress (obtained from the 4D as-planned model), and provide the clear comparison in an augmented reality environment between as-planned and as-built progress. A series of visualization techniques (e.g. colour and colour gradient) is developed to communicate and visualize detected discrepancies and progress performance metrics. Schedule deviations, construction sequence, budget distribution and earned value analysis metrics (cost performance and schedule performance indices) are also visualized. These techniques if automated could accurately and quickly communicate the progress situation on photographs and provide a powerful tool for prompt progress control decision making.

Keywords: augmented reality, building performance, progress monitoring, visualization.

INTRODUCTION

Owners are demanding faster, better and cheaper project delivery; however, under such conditions accomplishing desired performance during construction would be more difficult. Furthermore, most construction projects or their individual work phases are of relatively short duration and are generally conducted outdoors. Therefore onsite conditions are not permanent and are subject to interruptions and variations such as unforeseen weather conditions (Oglesby *et al*. 1989). These trends and challenges in construction projects require project managers to consider a systematic and comprehensive approach for monitoring and control of the construction progress. Project managers should easily assess and understand the progress status of the project, predict project completion and decide on proper

[1] mgolpar2@uiuc.edu

corrective action before any schedule and cost overruns occur (Song *et al*. 2005). Successful monitoring depends on an assessment of accurate measurement of progress, proper representation of discrepancies between actual and planned performance and timely updates of the schedule. Project management requires most up-to-date design, schedule, cost and performance data delivered in real time and in a comprehensive manner. This is achieved by obtaining an accurate picture of the project progress at any given point in time and implementing efficient control corrective actions.

Current progress monitoring

Current construction monitoring practice is not very efficient and effective, because:

1. *The current progress monitoring is time consuming and labour intensive*: Projects are not constantly monitored and hence it is very difficult to take corrective actions in real time. Current methods require manual data collection, and also extensive data extraction from construction drawings, schedules and budget information produced by project teams in which none is independent (Navon 2006). Field staff collect progress data from the construction site, analyse and deliver them to the project management team in a format specific to their areas of expertise: construction drawings, spreadsheets, bar charts, CPM or progress site photographs or videos. Such discrete and exhaustive reports are produced throughout the life of a project and do not explicitly convey level of performance, problems, their causes, and their impacts on the physical construction situation (Song 2005). Consequently, the project management team needs a lot of time and effort to sort out, prioritize and interpret these data.
2. *Quality of manually collected and extracted progress data is low*: Progress data may be error prone and expensive. Progress information is usually acquired through monitoring of the construction site by a team of field personnel. This may affect the quality of the manually collected data and make it error prone. The ability of anticipating possible outcomes only based on observations depends on the ability of the project management team and their expertise which in turn becomes subjective (Song 2005). The manual process is dependent on the status seen on site and does not reveal the impact of site circumstances on construction activity progressing forward.
3. *Existing methods of measuring progress are non-systematic and in generic terms*: Two of the most common ways to monitor progress are: (a) *Monitoring physical progress in percentile*: this performance metric is used in most construction fields, but it heavily relies on experience and knowledge of the project manager. This metric lacks objectivity and is inefficient at presenting progress due to its abstract nature of physical progress representation (Song 2005); (b) *Budget-based monitoring*: which is based on percentage of the budget paid to contractors with schedule-based inspections. This method of monitoring creates a time lag between progress estimations and schedule updates; besides judgements are usually subjective and misleading especially if a field manager makes an erroneous decision (Shih and Wang 2004). Without a specific comparative analysis on construction plans, sections, resources and cost data, wrong assumptions and inaccurate measurements on the progress status could be made. Mistakes such as overpaying, time delay and overlooking expected delay might occur. Such mistakes may often happen,

nevertheless if the construction process is visualized the progress status would be much clearer and such mistakes could be eliminated and more precise decisions could be made promptly (Song 2005).

4. *Progress monitoring reports are visually complex*. According to Kerzner (2001) and Song *et al*. (2005), 30 to 40 different visual methods are currently being used to represent construction information throughout the life cycle of a project. These graphics and charts contain four sets of information: time, cost, resources and performance to provide an accurate picture of the relations between them. Among various types of information representation, the choice is dependent on the intended audience. For example, upper level management may be interested in costs and integration of activities with very little detail. Summary-type charts normally suffice for this purpose. Daily practitioners, on the other hand, may require as much detail as possible in daily schedules. If the schedule is to be presented to the client, then the presentation should include cost and performance as well (Kerzner 2001). However none of these methods effectively presents multivariable information (i.e. time, cost, resources and performance) in a holistic manner, nor do they reflect the unique circumstances of progress situation (Song *et al*. 2005). It is extremely hard for a project manager to monitor and control all aspects of a project on the basis of first-hand observation alone. Significant information may be disguised during meetings by field professionals. Text-based information is often overly detailed or too technical. Nonetheless, most organizations do not have standardized reporting procedures, which further complicates the situation (Song *et al*. 2005). Under such circumstances, most of the time in schedule revision and coordination meetings is devoted to describing problems and explaining the rationale of decisions and very little time is spent on the real decision making such as the discussion about what-if scenarios (Golparvar Fard *et al*. 2006). The major reason for this is the limitation of proper media that represents these construction discrepancies (Lee and Peña-Mora 2006). It may be difficult to understand the situation clearly and quickly as these representations lack information relating to spatial context and complexities of project components (Koo *et al*. 2000).

In such circumstances, an effective representation of progress discrepancy is needed to save time spent on describing and explaining the situation in the meeting. Visualization of progress monitoring is reported as an effective monitoring process and can assist the project manager in cutting cost and reducing the time for gathering and interpreting data, understanding complex situations and developing better counteractive procedures (Lee and Peña-Mora 2006). Particularly when clients' capability and need to understand complex construction situations are considered, the benefits of visualization techniques would be maximized (Lee and Peña-Mora 2006). As an effort to address this issue visual representation of progress status on time-lapse photographs is proposed. It aims to visualize the actual progress by superimposing the planned progress (obtained from the 4D (3D + time) model) over the photograph (acquired from time-lapse photography or filming) and thus, provide clear comparison between as-planned and as-built progress in an AR (augmented reality) environment. Synchronized time-lapse photography and virtual 4D creates the progress information seamlessly. The methodology proposed to represent performance metrics is based on the earned value analysis method. This method would demonstrate all critical information for the project manager regarding the actual conditions, potential issues, prior concerns and future scenarios.

VISUAL REPRESENTATION OF PROGRESS METRICS

Proposed progress data collection technique

For the proposed application, the inputs are an as-planned 4D model of the project and time-lapse photographs captured by onsite cameras. The as-planned 4D model contains 3D representation of construction components (spatial information on product model) and planning and scheduling information (the process model). The time-lapse photographs contain a sequence of images taken from a fixed point of view that represents the as-built model. The ultimate goal is to automatically overlay and compare the information in the set of images with the as-planned model which allows determining and updating of actual progress status. Figure 1 shows an example of time-lapse photographs taken from a camera on a construction site showing progress.

Figure 1: Examples of progress images from a construction site time-lapse photography camera

Visualization process

Once these progress photographs are collected, the camera should be calibrated, i.e. the relationship between 3D-model coordinates and the corresponding coordinates of the site photograph should be established. Having set the relationship, a camera with the same parameters of the real-world camera is put into the 4D environment. Following that, an image taken from the 4D model would be superimposed on top of the site photograph taken at the same time. This step establishes the correspondence between the site photograph and the planned image. Figure 2 shows an example of a 3D model perspective view where the camera has been registered in the 4D environment superimposed on the progress photograph. The overlaid photograph shows the expected physical progress on top of the site photograph. Superimposition of images provides a clear comparison of what was intended (as-planned) and what has been performed (as-built) (Lee and Peña-Mora 2006).

After this step, a comparison between the as-planned model and as-built model could be easily made. Once the corresponding photograph patch (a small portion of the site photograph of a specific construction component) is found, a series of pattern recognition and image analysing techniques would be applied to extract information from the extracted patch of the photograph. There are robust techniques in computer vision and pattern recognition that could facilitate this process (Forsyth and Ponce 2003). Prior to performing any pattern recognition process, there is a need to establish how these results could be visualized when the superimposition is done. For that, a series of manual comparisons between as-planned models of a series of construction series of manual comparisons between as-planned models of a series of construction projects with their actual progress photographs is done and the parameters of progress monitoring are visualized.

In the following section, the authors will first look into the progress metrics that need to be shown and then will establish visualization techniques representing the project performance.

Figure 2: From top to bottom: site photograph, 3D perspective of the expected progress with the same view as the photograph, and superimposed 3D model on top of the site photograph

Visualization of progress monitoring metrics

Once superimposition of the images is complete and progress status is identified based on comparison of site photographs with the as-planned model, monitored information could be visualized. As mentioned earlier, earned value analysis is used to represent the progress status of the project. Table 1 demonstrates the required monitoring information for project managers during construction.

It is clear that for every step forward in construction progress, the number of 3D model components increases in the 4D environment and as a result visual representation could potentially become more complex (Song *et al*. 2005). Therefore, in order to effectively and consistently use these visualization techniques, a colour spectrum suggested by Song *et al.* (2005) is extended for this work. Table 2 demonstrates that colour spectrum.

Table 1: Critical information sets for project managers during construction phase

	Metric	Description	Visualization form
Basic information	Activity	Description of activities	NA
	Responsibility	List of entities assigned to the activities	NA
	Criticality	Type of criticality	Colour coding
	Float	Amount of float	Colour coding
		Cost distribution of each item based on the percentage of total project cost	Colour coding
Actual performance	% Complete	Percent of work performed	Colour coding
	Productivity	% physical completion / % QAB (quantity-adjusted budget) person-hours used	Colour coding
	CPI	Value of cost performance index	Colour coding/CPI diagram
	SPI	Value of schedule performance index	Colour coding/SPI diagram
Forecasting information	Schedule deviation	Time deviation	Colour coding
	Cost deviation	Cost savings and overruns	Colour coding

Table 2: Critical information sets for project managers during construction phase and the colour spectrum (adapted from Song *et al*. 2005)

Performance	Poor	Perfect	Excellent
Criticality	Critical	Near critical	Non-critical
Float	Float decrease	Float No	Float increase

According to Table 2, blue colour is used to represent those components that need the least management effort while red colour represents components that need more project control action. For instance, in order to represent schedule/cost deviations, red colour could be used on those components that are behind schedule or over budget, green colour for those that are perfect and blue colour for those that are in excellent progress condition. Figure 3 shows the photograph taken from the site and the superimposed image representing status of the progress with different colours.

Cost performance index/schedule performance index

As mentioned before, cost and schedule performance indices (CPI/SPI) of earned value analysis provide robust measurements of current progress status and also serve as key forecasting tools for project management. Song *et al*. (2005) suggested that these two performance indices could be simultaneously represented using a quadrangle colour scheme. Figure 4 shows how the colour spectrum has been modified to represent these two indices simultaneously.

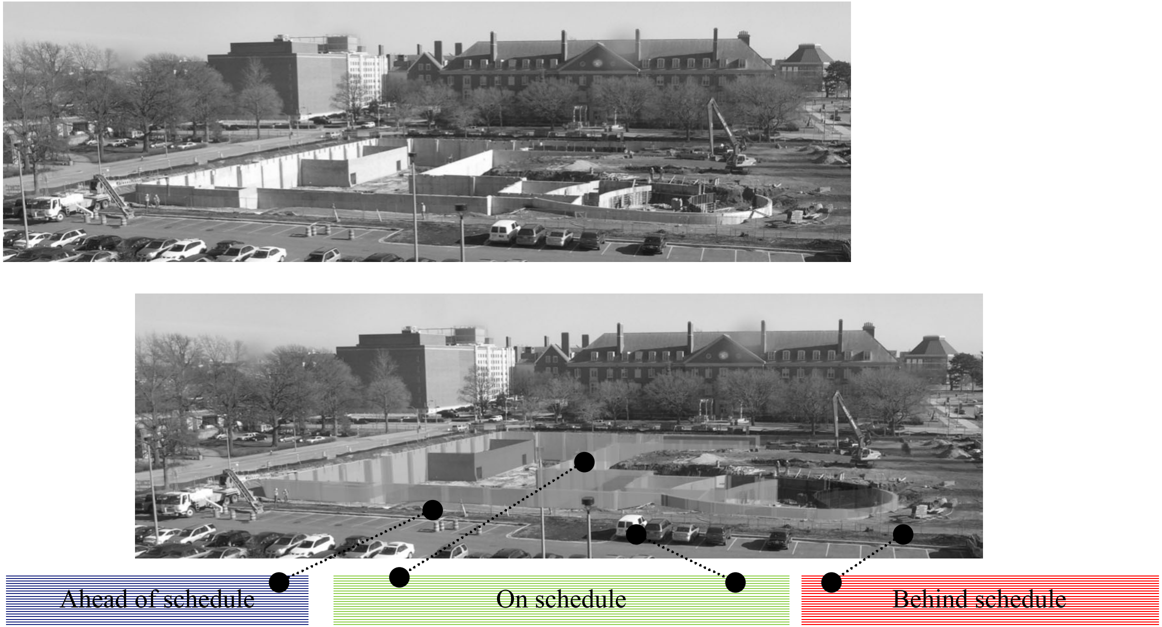


Figure 3: From top to bottom: site photograph, superimposed photograph and colour coding convention (this is a conceptual image and does not reflect the real performance of the construction company)

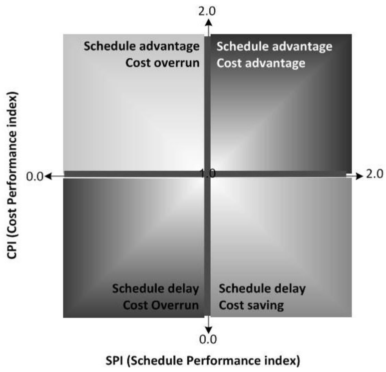


Figure 4: Quadrangle colour scheme of performing indices (extended from Song *et al.* 2005)

Figure 5 demonstrates application of the quadrangle colour scheme on a site photograph. As seen in the figure, foundation walls constructed over a period of five months are represented with different colours. At the current status of the project, there is a delay and cost overrun associated with half of the constructed components. Moreover cost on some other parts is reported to be higher than budgeted cost (represented in yellow colour).

Figure 5: Visual representation of overall project performance (this is a conceptual image and does not reflect the real performance of the construction company)

Concurrent representations of schedule deviations/floats
One of the other visualization methods used to represent deviations/floats is colour gradients. Figure 6 represents the convention suggested by Song *et al*. (2005).

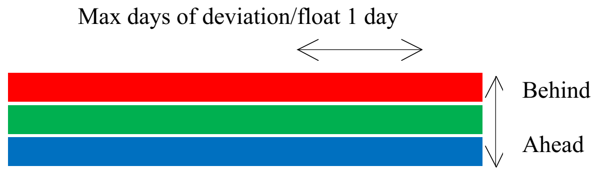


Figure 6: Visual representation of schedule deviation/floats (extended from Song *et al*. 2005)

In this study, the same convention is applied to the site photographs to represent progress deviations. Figure 7 shows an example where concrete pouring has been delayed. As seen, the pouring is happening at the time of taking the photograph. There are parts of the foundation wall that are three weeks behind schedule (i.e. shown in transparent red) and other parts are only a week behind schedule (i.e. represented in solid red).

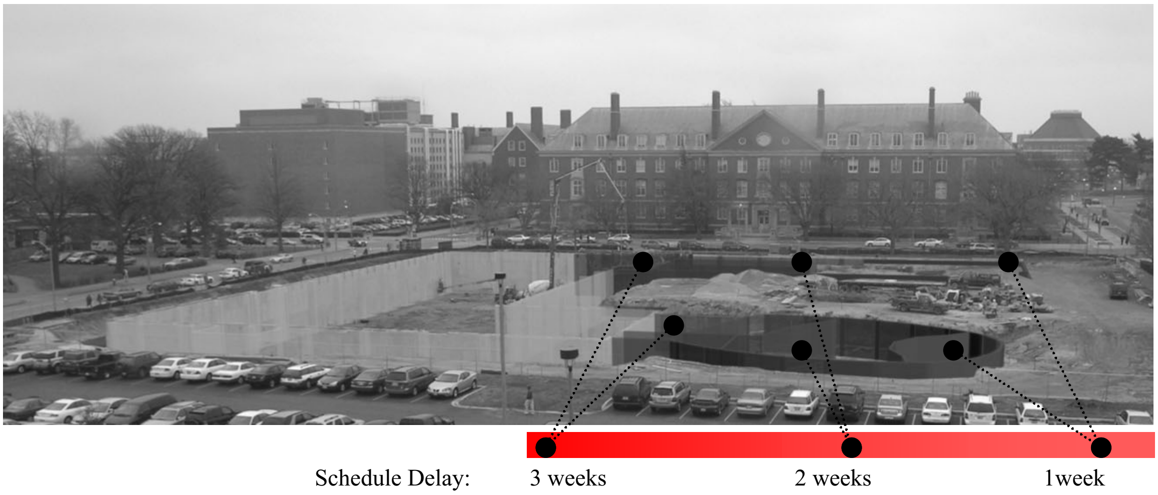


Figure7. Visual representation of schedule deviation/ floats (Disclaimer: This is a conceptual image and does not reflect the real performance of the construction company)

CONCLUSIONS

This paper discussed techniques for visualization of construction progress monitoring, particularly for progress monitoring using time-lapse photography. Compared to other traditional and automated methods used for progress monitoring, the proposed method integrates as-planned with as-built information and visually represents progress status. It could be a consistent and realistic method for representing project performance metrics where spatial and temporal information are represented in a very simple manner allowing project progress prediction and control decision making.

The value of the represented method would be maximized once the whole process is automated, allowing accurate and quick communication of progress situation. This requires further research on configuration of time-lapse photography cameras on site, wherein location and orientation of cameras that satisfactorily detect the progress should be determined. Issues such as occlusion and illumination changes within photographs should also be considered. Once the camera is all set, the progress detection method based on image analysis techniques needs to be robustly designed to

Structure (WBS) represented in the 4D environment should also be developed to incorporate information on temporary structures (e.g. formwork, scaffoldings) for progress analysis purposes.

The visualization techniques also need to be further tested and validated to make sure it represents progress status under different site and weather conditions. Currently authors are conducting case studies, the results of which would be reported in near future.

AKNOWLEDGEMENTS

The authors would like to acknowledge the help and support for this paper by Kip Mecum, Director of Emergency Planning with the Division of Public Safety and all the people at Facilities and Services and College of Business of the University of Illinois at Urbana-Champaign. Sharing of valuable information for the College of Business Instructional Facility project by Gilbane Construction Company and financial support of National Science Foundation is greatly appreciated.

REFERENCES

Forsyth, D and Ponce, J (2003) *Computer vision, a modern approach*. New Jersey: Prentice Hall.

Golparvar Fard, M, Staub-French, S, Po, B and Tory, M (2006) Requirements for a mobile interactive workspace to support design development and coordination. *In*: *Joint International Conference on Computing and Decision Making in Civil and Building Engineering*, Montréal, Canada, 3578–96.

Kerzner, H (2001) *Project management: a system approach to planning, scheduling and controlling*. New York: John Wiley.

Koo, B and Fischer, M (2000) Feasibility study of 4D in commercial construction. *Journal of Construction Engineering and Management*, **126**(4), 251–60.

Lee, S and Peña-Mora, F (2006) Visualization of construction progress monitoring. *In*: *Proceedings of Joint International Conference on Computing and Decision Making in Civil and Building Engineering*, 2527–33.

Navon, R (2006) Research in automated measurement of project performance indicators. *Journal of Automation in Construction*, **16**(7), 176–88.

Oglesby, C, Parker, H and Howell, G (1989) *Productivity improvement in construction*. McGraw-Hill Inc.

Shih, N and Wang P (2004) Point-cloud-based comparison between construction schedule and as-built progress: long-range three-dimensional laser scanner’s approach. *Journal of Architectural Engineering*, **10**(3), 98–102.

Song, K, Pollalis, S and Peña-Mora, F (2005) Project dashboard: concurrent visual representation method of project metrics on 3D building models. Paper presented at the International Conference on Computing in Civil Engineering, ASCE, Cancun, Mexico.

INTEGRATING EMERGENT PROBLEM SOLVING WITH CONSTRUCTION KNOWLEDGE MANAGEMENT SYSTEM

Wen-der Yu[1], Cheng-te Lin[2], Cheng-tien Yu[2], Shen-jung Liu[3], Huai-ching Luo[3], Pei-lun Chang[3]

[1]*Institute of Construction Management, Chung Hua University, Hsinchu, Taiwan*
[2]*Department of Civil Engineering, National Taiwan University, Taipei, Taiwan*
[3]*Department of Business and Research, China Engineering Consultants Inc., Taipei, Taiwan*

The construction industry is faced with emergent problems and crises every day. Speed and efficiency of problem solving plays a key role not only for the survival but also for improving the service quality of a construction firm. This paper presents a case study on the integration of a knowledge management system (KMS) with an emergent problem-solving system (SOS), namely Knowledge Management integrated Problem Solver (KMiPS), in a local A/E consulting firm. It is found that such integration may result in major benefits that contribute to the improvement of the firm's long-term competitiveness. The case study found remarkable benefits in time, man-hours and cost improvement. Moreover, the knowledge sharing on emergent problem solving among the participating engineers/managers enriches the virtual repository of intangible intellectual assets for the firm.

Keywords: case study, information technology, knowledge management, problem solving.

INTRODUCTION

Construction management activities are fundamentally problem-solving activities (Li and Love 1998), where construction managers and engineers are faced with emergent problems and crises in their daily business operations, e.g. the bidding decision, design modifications, material selections, construction method determinations, site condition variations, change orders, dispute resolutions, etc. Some of the problems are due to the internal nature of the industry, such as the contracting system and fragmented organization; others are caused by the external factors, such as the uncertainty in construction works or environment (e.g. site or weather conditions). No matter which reason causes the emergent problems, the requirements for problem solving are always correctness, speed and efficiency; that is, the problems should be solved correctly, in the shortest time and cost-effectively.

Li and Love (1998) found that construction problems pose several characteristics that should be tackled in order to solve them quickly, correctly and cost-effectively, such as ill-structure nature, inadequate vocabulary, little generalization and conceptualization, temporary multi-organization (TMO), uniqueness of problems, and difficulty in reaching the optimal solution. Two areas of problem-solving research tackle the above-mentioned issues: cognitive science and the decision support system

[1] wenderyu@chu.edu.tw

(DSS). Even though Li and Love had pointed out the importance of research on construction problem solving, no quantitative measures were provided on how well the two approaches have performed in real world implementation.

In this paper, a case study is conducted on a leading A/E consulting firm (China Engineering Consultants Inc., CECI) in Taiwan focusing on the knowledge management system (KMS) for solving emergent construction problems, which forms a Knowledge Management integrated Problem Solver (KmIPS). The KMiPS approach is different from the two approaches described by Li and Love (1998), being based rather on the theory of organizational knowledge creation proposed by Nonaka (1994). Both quantitative and qualitative benefit evaluations are performed. The primary objective of this paper is to present the lessons learned in the case study A/E firm and hopefully such lessons may benefit other construction organizations that are suffering with problem solving every day.

LITERATURE REVIEW

Review of problem solving in construction

Three perspectives of construction problem solving are reviewed in this section, including two perspectives mentioned by Li and Love (1998) and the organizational knowledge creation perspective proposed by Nonaka (1994).

Cognitive processing perspective

The cognitive perspective of problem solving focuses on developing models to explain the cognitive phenomena that occur in the problem solver's mind during the problem-solving process. Simon proposed an 'intelligence-design-choice' (IDC) model (Simon 1965); Newell and Simon modified the IDC model to the 'generate-and-test' (GAT) model (Newell and Simon 1972). In that, the potential solutions to the problem are generated and tested by the problem solver to evaluate their fitness to the solution goals. Other cognitive models can be found in Lang *et al*. (1978) and Cowan (1986). The primary objective of cognitive science is to try to equip the problem solver with explanations and planning capabilities for optimal solutions (Berger *et al*. 1986). However, the findings in cognitive modelling are not strong enough for practical implementation in construction problem solving (Li and Love 1998).

Information processing perspective

In the past decades, researchers have engaged in developing problem-solving systems that can systematically solve well-structured problems step by step. Such systems are named decision support systems (DSSs). Two basic approaches to develop a DSS are operation research (OR) and artificial intelligence (AI). Examples of OR approach include the linear programming (LP) (Srour *et al*. 2006), integer programming (IP), dynamic programming (DP) (Moselhi and Hassanein 2003), system simulation, etc. The AI approach requires a representation scheme to describe the construction problems for the domain experts. Popular AI techniques adopted for developing a DSS include expert systems (ES), case-based reasoning (CBR), artificial neural network (ANN), fuzzy logic (FL), genetic algorithm (GA), etc.

In contrast to cognitive processing, the information processing perspective tackles the problem-solving task in three phases (Li and Love 1998): (1) the formulation of an explicit statement of goals for the problem to be solved; (2) identification of solution space; and (3) selection of the optimal alternative among all feasible solutions. However, either the problem formulation in OR approach or the problem representation in AI approach is difficult for the problem solver owing to the nature of construction problems.

Organizational knowledge creation perspective
Nonaka (1994) proposed a four-dimensional model for organizational knowledge creation (also known as ‘spiral of organizational knowledge creation’) that can be considered as another approach for problem solving. The concept of Nonaka’s spiral of organizational knowledge creation is depicted in Figure 1, where the vertical axis divides the knowledge types into ‘explicit’ and ‘implicit’. The horizontal axis differentiates the ontology of knowledge-creating entities, e.g. individual, group, organization and inter-organization. The problem is solved via the process of knowledge creation. In other words, the problem is communicated between the questioner and the problem solver through ‘socialization’; then, the problem solver documents the problem in words or drawings through ‘externalization’; with some aids of external databases/knowledge bases, the problem solver figures out the solution through ‘combination’; finally, the experience of problem solving is accumulated in the problem solver’s mind for future use through ‘internalization’. The four types of knowledge transformation can be viewed as the phases of the problem-solving process.

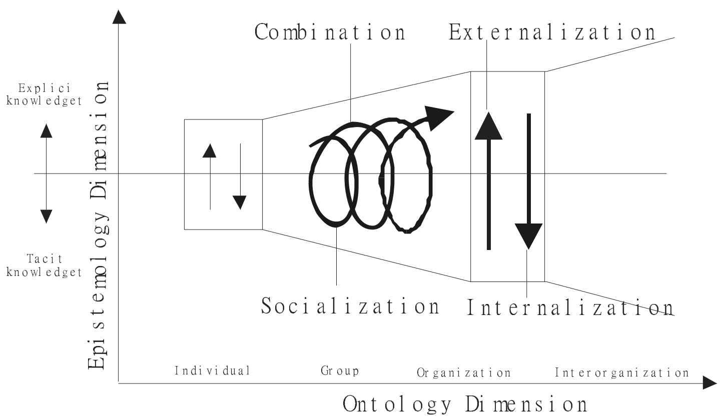


Figure 1: Spiral of organizational knowledge creation (Nonaka 1994)

The theory of organizational knowledge creation forms the theoretical foundation of a modern knowledge management system (KMS). From Nonaka’s viewpoint, problem solving is a process of knowledge creation through socialization, externalization, combination and internalization. Modern KMSs are built on the communities of practice (COPs), which provide forums for members of the organization (or temporary multi-organization) to participate in problem-solving processes in a virtual or real world community. Such a phenomenon is also called the ‘Medici effect’ (Johansson 2002).

Johansson (2002) carried out exhaustive observations of great inventions of the world and proposed a new concept of ‘the Medici effect’ for knowledge creation. According to Johansson, the innovators are changing the world by stepping into the ‘intersection’: a place where ideas from different fields and cultures meet and collide, ultimately igniting an explosion of extraordinary new discoveries. Johansson explains that three driving forces (the movement of people, the convergence of scientific disciplines, and the leap in computational power) are increasing the number and types of intersections we can access. The Medici effect provides a theory for how the communities of practice (COPs) work in a KMS. This approach is adopted by the case study A/E firm in solving its problems.

Review of knowledge management in construction

Knowledge management in construction

Kim *et al*. (2003) proposed a practical method for capturing and representing knowledge that is critical in knowledge management. The method employs a knowledge map as a tool to represent knowledge of a firm. The procedure consists of six steps: (1) defining organizational knowledge; (2) analysing a process map; (3) extracting knowledge; (4) profiling knowledge; (5) linking knowledge; and (6) validating map knowledge. Effective knowledge maps help identify intellectual capital, socialize new members, enhance organizational learning, and anticipate impending threats and/or opportunities (Mezher *et al*. 2005).

Performance measurement of the KMS

There are very few research reports found in the literature on performance evaluation of a KMS. The most relevant work discovered in the literature was a work done by del-Rey-Chamorro *et al*. in Cambridge University (del-Rey-Chamorro *et al*. 2003). They developed an eight-step framework to create performance indicators for knowledge management solutions. Del-Rey-Chamorro *et al*.'s work can be very useful for creating performance indicators of a KMS; however, their work was primarily developed based on the observations of KMS in manufacturing industry. Swaak *et al*. (2000) conducted a survey and concluded that there are two major measurement approaches related to knowledge management results: (1) the questionnaire approach; (2) the multiple indicators approach. A recent work reported by Mezher *et al*. on a KMS in a mechanical and industrial engineering consulting firm (Mezher *et al*. 2005) in the Middle East is closely related to this paper. Their paper details the step-by-step implementation of a KMS in the case study company and lessons learned on the benefits of KMS implementation. Unfortunately, their work didn't describe the evaluation of the performance of the KMS.

BACKGROUND OF CASE STUDY

The case study firm and KMS

The case study A/E firm is one of the top three A/E firms in Taiwan. It was established in 1969 primarily for the purpose of promoting Taiwan's technology and assisting in the economic development of Taiwan and other developing countries. The number of full-time members of staff of the firm is about 1700. The annual revenue of case study A/E firm is around TW$4 billion (US$128 million). According to the information disclosed by the firm, more than 1700 A/E projects were finished in the past 30 years. The total volume (construction budget) of the finished projects exceeds US$300 billion.

The implementation of a KMS in the case study A/E firm started five years ago. Unlike most of other examples of KMS implementation, the A/E firm chose to develop the KMS completely by their own staff members without help of external consultants. Commercial software, Microsoft SharePoint® was adopted to develop the KMS. The system development took one year to complete the prototype. The prototype KMS began to operate after one year of the project commencement. More than 40 communities of practice (COP) were established.

The emergent problem-solving system (SOS)
The SOS system is a special design of the KMS of the case study A/E firm, which provides a tentative forum for emergent problems encountered by engineers/managers. Once the problem is posed as a SOS problem, it is posted in the SOS board on the first page of the KMS for emergent discussions. Such arrangement forces every participant of the KMS to take a look at the posed problem. In this way it generally receives attention and usually has a better chance to be solved by respondents. A problem posed on the SOS board that receives no response within one working day will be automatically removed and transferred to the relevant COP. After then, it becomes regular topic for discussion in the COP.

Type of emergent problems
There are basically 11 categories of emergent problems facing the case study A/E firm: (1) requests of client – requests of the client can be very diversified but emergent; (2) reaction to accident; (3) dispute/contract execution – interpretation of contract articles; (4) material and equipment – onsite activities problems; (5) safety/environment – problems with regulations of the government; (6) requests for engineering information – including the information of bid items or a design, construction method; (7) completion and transfer; (8) SPEC and criteria – technical specifications or design codes; (9) problems with contractors/subcontractors – such as schedule extension or claims of additional cost reimbursement; (10) internal process of the firm – the business/administration process of the firm; (11) others – all problems not belonging to the above categories.

In this case study, the more than 800 problem-solving cases of CECI were collected from June 2004 to September 2006. After reviewing and screening, 586 emergent cases were selected for the case study. The distribution of the 586 emergent problems in the 11 categories is shown in Table 1.

Table 1: Distribution of the 586 emergent problems in the case study A/E firm

No.	Type of emergent problem	Count	%
1	Requests of client	35	6.0%
2	Reaction to accident	6	1.0%
3	Dispute/contract execution	22	3.8%
4	Material and equipment	83	14.1%
5	Safety/environment	24	4.1%
6	Request of engineering information	209	35.7%
7	Completion and transfer	3	0.5%
8	SPEC and criterion	152	25.9%
9	Problems with contractors/sub-contractors	8	1.4%
10	Internal process of the firm	7	1.2%
		586	100%

KNOWLEDGE MANAGEMENT INTEGRATED PROBLEM SOLVER (KMIPS)

In this section, the emergent problem-solving method adopted by the case study A/E firm is an emergent problem solver integrated with the knowledge management system (KMS) of the firm – tentatively named Knowledge Management integrated Problem Solver (KMiPS) – is described in detail.

System framework

The system framework of KMiPS is depicted in Figure 2. The KMiPS is comprised of four major elements: (1) problem diagnosis module – a pre-screening module that assesses the level of emergency of the posed problems; (2) SOS – a specialized community of practice (COP) with the top priority on the firm's enterprise information portal (EIP), which provides a forum for all staff and domain experts to participate in the problem-solving process; (3) domain experts – a pool of the firm's internal and external specialists in all areas related to the services provided by CECI; (4) the firm's KMS.

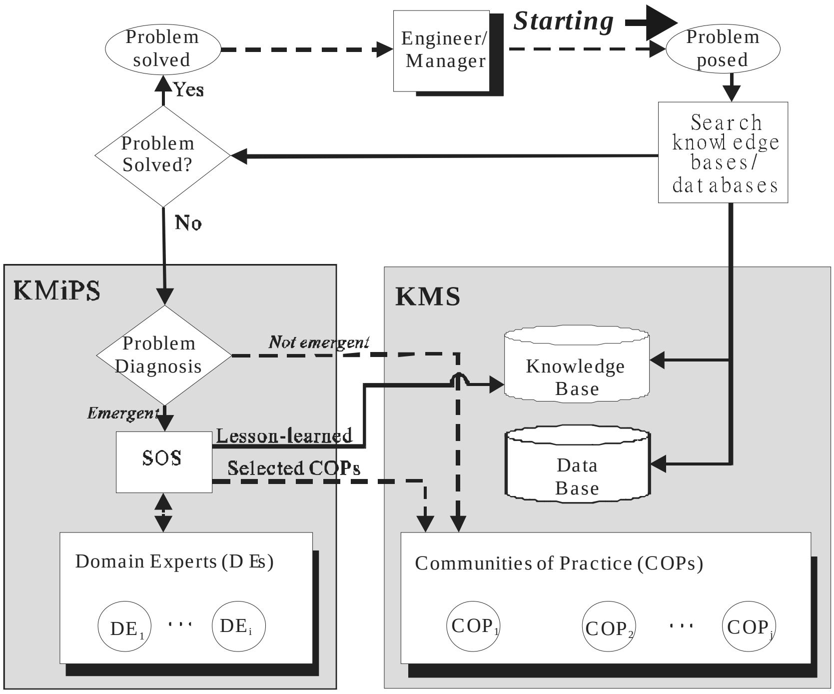


Figure 2: Framework of KMiPS

System operation procedure

The operation of KMiPS shown in Figure 2 follows the procedure: (1) as the problem is posed by any engineer/manager, he/she should search the knowledge bases and databases of the firm first and enter the KMiPS if the problem is not solved; (2) the problem diagnosis module assesses the emergency level to determine if the problem should be posted in the SOS system; (3) if the emergency level of the posed problem is low, it is posted in the related COPs of KMS; (4) if the problem is emergent, it is posted in SOS on the first page of EIP and the selected COPs of KMS simultaneously; (5) domain experts (DEs) from within and outside the firm participate in discussions of the problem solution through a organizational knowledge creation process; (6) as the solution is obtained, the lesson learned from the problem solving is documented into the knowledge base of the KMS for future problem solving.

BENEFIT ANALYSES

The KMiPS described in the previous section has been proven very successful not only in solving emergent problems encountered by the engineers/managers of the firm, but also in accumulating the lessons learned from executed problem-solving cases. In this section, both quantitative and qualitative benefits of the KMiPS system in problem solving are analysed.

Data collection and questionnaire survey

The SOS system was implemented from 1 June 2004. The period of data collection is from 1 June 2004 to 26 September 2006. In total, 654 SOS problem-solving cases were collected. A web-based system was developed for questionnaire survey and data collection. For every SOS case, both the questioner and respondents were surveyed with the KMS. The 'questioner' was asked to provide the following information: (1) whether the problem was solved or not; (2) evaluation of the 'level of contribution' (scale 1–5) to each solution from the respondents; (3) additional time spent on developing the final solution; (4) the numbers of meetings, phone calls and interviews required to develop a similar solution via the traditional approach; (5) average time required for meetings, phone calls and interviews required respectively to develop a similar solution via the traditional approach. The 'respondent' was asked to provide the following information: (1) the time required to develop the solution; (2) the time spent in the office and after work, respectively, to develop the solution. In all, 5011 questionnaire surveys were conducted via the KMS. Finally, 454 complete SOS cases and 3250 valid responses were obtained.

Quantitative benefit analysis

In order to measure the benefits resulting from the KMiPS system, a quantitative benefit model was proposed by Yu *et al*. (2006) to quantify (1) time benefit – saving of time required to solve a problem with KMiPS compared with the time required in the traditional process; (2) man-hour benefit – saving of man-hours required to solve a problem with KMiPS compared with the man-hours required in the traditional process; (3) cost benefit – saving of cost spent to solve a problem with KMiPS compared with the cost spent in the traditional process. Owing to the limitation of the paper, the quantitative models are not reiterated here. Any interested reader is referred to Yu *et al*. (2006) for details.

The quantitative benefits resulting from KMiPS based on the models described previously are: 50.88% of time benefit, 63.53% man-hour benefit and 84.40% cost benefit based on the quantitative models of Yu *et al*. (2006). Other quantitative data describing the benefits of KMiPS are shown in Table 2. From Table 2, it can be seen that the KMiPS saves 8279 man-hours in solving the 454 emergent problems compared with the traditional approach, and this means a cost saving of US$431 354.

Table 2: Data of benefits resulted from KMiPS

Decreased meetings (times)	250
Decreased meeting time (hours)	192
Decreased phone calls (times)	1273
Decreased phone call time (hours)	219
Decreased interviews (times)	324
Decreased man-hours (hours)	8279
Total saving (US$)	431 354

Qualitative benefit analysis

In contrast to the quantitative benefits, identification of the qualitative benefits resulting from KMiPS is difficult. In this research the qualitative benefits were identified through interviews with the engineers/managers of CECI who participated in KMiPS problem-solving. The identified quantitative benefits include (but are not limited to): (1) increase of the firm's intellectual property – during the process of organizational knowledge creation, all participants (including those who read but didn't participate in discussions) accumulate their knowledge related to the posed problem, and the accumulated knowledge may be used another day; (2) solving of problems that could not be solved before – in the traditional approach, the problem is discussed and solved by a taskforce with only limited members from different disciplines, which may exclude the real experts on the problem (who have solved a similar problem before) due to their unavailability for any reason; (3) increase of the Medici effect – when integrated with a KMS, the KMiPS can incorporate all staff of the firm and thus maximize the Medici effect and increase the possibility of problem solving; (4) improvement of client satisfaction – as the KMiPS shortens the required problem-solving time, client satisfaction is significantly greater; (5) improvement of the sense of belonging – the 'sense of belonging' to an organization is a spiritual property that promotes the competitiveness of the firm; with KMiPS engineers/managers and other staff share the pressure of work and the pleasure of problem solving, which improves the 'sense of belonging' of all participants to the organization.

DISCUSSION

Limitations of analysis methodology

The analysis of benefits generated by the proposed KMiPS is based on a quantitative model proposed by Yu *et al*. (2006). In that model, the benefits of a KMS are measured by questionnaire surveys with participants to compare the required efforts for problem solving with both traditional and the proposed approaches. An essential assumption for this model is that the participants are able to 'compare' required parameters of the two approaches. Such assumptions are made in this research, too.

Moreover, the results reported in this paper are based on a case study of a local A/E consulting firm. Different results may be obtained depending on the types of firms, the culture of the organizations and the KM platform adopted.

Merits of KMiPS

Integration of cognitive and information processing perspectives

The KMiPS adopts both the cognitive and information processing problem-solving perspectives. It utilizes the KMS (an advanced information technology) for information processing (searching of knowledge base and database, and problem communication). Moreover, problems with the traditional cognitive science approach are improved with formulated lessons learned of solved cases, so that they can be searched and reused by users.

Improvement of generalization and conceptualization

Generalization and conceptualization (of the proposed and implemented solutions to the posed problems) are enhanced in the KMiPS by matching the domain experts in the solution for a specific problem. The problem of no optimizing or improvement mechanism in the traditional cognitive approach is also improved by a recursive process of solution discussion, where the questioner 'socializes' (the term employed by Nonaka) with respondents via a series of discussions in SOS. The respondent can improve his/her solution based on the solution of previous respondents; and the questioners select the best solution before he/she develops the final solution.

Accumulating lessons learned
The problem of 'temporary-multi-organization' (TMO) in the construction industry is also better tackled by the KMiPS, since the previous problem-solving cases are accumulated with the KMS and modified by the questioners and respondents participating in KMiPS problem solving. Such accumulation of lessons learned not only provides a source of the organization's intelligence, but also develops the learning capability of an organization. It expands the learning scope of the traditional individual cognitive problem-solving approach.

CONCLUSIONS AND RECOMMENDATIONS

In this paper, a case study is conducted on a leading A/E consulting firm in Taiwan. From the case study, a new approach for emergent problem solving, named Knowledge Management integrated Problem Solver (KMiPS) is proposed, which integrates the emergent problem system (namely, SOS system) with the knowledge management system (based on Microsoft SharePoint® platform) to form a new approach for problem solving. The KMiPS approach combines both cognitive and information processing perspectives of traditional problem-solving approaches. It tackles problems encountered in the traditional approaches and provides desirable functions (e.g., improvement of generalization and conceptualization, and accumulating lessons learned). Both quantitative and qualitative benefits are assessed with the KMiPS system. The quantitative benefit analysis shows remarkable time, man-hour and cost improvements based on 454 historical cases. Other quantitative data show 8279 man-hours or US$431 354 of savings. It is thus concluded that the KMiPS approach is very beneficial for the case study A/E firm. It can also benefit other organizations in the construction industry in solve emergent problems.

It is recommended to apply the KMiPS to other types of organizations in the construction industry, such as contractors or EPC firms. The efficiency of problem solving in different types of construction problems needs further research, too. An advanced mode of problem solving to improve the efficiency of problem solving is also worthy of research.

ACKNOWLEDGEMENT

The founding of this research project was partially supported by the National Science Council, Taiwan, under project No. NSC 95-2221-E-216-049. Sincere appreciations are given to the sponsor by the authors. The valuable case study information presented in this paper was provided by CECI, Taipei. The authors would like to express sincere appreciations to the China Engineering Consultants, Inc., Taipei, Taiwan.

REFERENCES

Berger, D E, Pezdek, K and Banks, W P (1986) *Applications of cognitive psychology*. Hillsdale, NJ: Lawrence Erlbaum.

Cowan, D A (1986) *Developing a process model of problem recognition*. *Academy of Management Review*, **11**(4), 763–6.

Del-Rey-Chamorro, F M, Roy, R, van Wegen, B and Steele, A (2003) A framework to create key performance indicators for knowledge management solutions. *Journal of Knowledge Management,* **7**(2), 46–62.

Johansson, F (2002) *The Medici effect: breakthrough insights at the intersection of ideas, concepts, and cultures*. Cambridge, MA: Harvard Business School Press.

Kim, S, Suh, E and Hwang, H (2003) Building the knowledge map: an industrial case study. *Journal of Knowledge Management*, **7**(2), 34–45.

Lang, J R, Dittrich, J E and White, S E (1978) Managerial problem solving models: a review and a proposal. *Academy of Management Review*, **3**(4), 854–66.

Li, H and Love, P E D (1998) Developing a theory of construction problem solving. *Construction Management and Economics*, **16**, 721–7.

Mezher, M, Abdul-Malak, M A, Ghosn, I and Ajam, M (2005) Knowledge management in mechanical and industrial engineering consulting: a case study. *ASCE Journal Management in Engineering*, **21**(3), 138–47.

Moselhi, O and Hassanein, A (2003) Optimized scheduling of linear projects. *ASCE Journal of Construction Engineering and Management*, **129**(6), 664–73.

Newell, A and Simon, H A (1972) *Human problem solving*. Englewood Cliffs, NJ: Prentice Hall.

Nonaka, I (1994) A dynamic theory of organizational knowledge creation. *Organization Science*, **5**(1), 14–37.

Simon, H A (1965) *The shape of automation*. New York: Harper & Row.

Srour, I M, Haas, C T and Morton, D P (2006) Linear programming approach to optimize strategic investment in the construction workforce. *ASCE Journal of Construction Engineering and Management*, **132**(11), 1158–66.

Swaak, J, Lansink, A, Heeren, E, Hendriks, B, Kalff, P, Den Oudsten, J-W, Böhmer, R, Bakker, R and Verwijs, C (2000) Measuring knowledge management investments and results: two business cases. Paper presented at the 59th AEPF-Tagung, 3 October 2000, Bremen, Germany.

Yu, W D, Chang, P L and Liu, S J (2006) Quantifying benefits of knowledge management system: a case study of an engineering consulting firm. *In*: *Proceedings of International Symposium on Automation and Robotics in Construction 2006 (ISARC 2006)*, Session A4 – Planning and Management (1), 3–5 October 2006, Tokyo, Japan.

KNOWLEDGE-BASED DECISION SUPPORT TOOL FOR DURATION AND COST OVERRUN ANALYSIS OF HIGHWAY CONSTRUCTION PROJECTS

C. Arun[1]

[1]*Civil Engineering Group, Birla Institute of Technology and Science, Pilani, Rajasthan, India*

Highway construction is considered to be one of the important infrastructure developments of any nation, and it involves numerous uncertainties in its planning and execution stages. In addition to uncertainties in the planning stage, which mainly deals with resources, time and technology, uncertainties in the execution stage are mostly site-specific. Owing to this high level of uncertainty, risks associated with site delays are unpredictable and require specific attention by project personnel. The conventional technique for combating time and cost overruns adopts project monitoring using bar charts which are prepared by other conventional scheduling techniques that necessitate crashing of entire train of activities which may or may not be affected by the delay. Hence this paper deals with an innovative decision support tool that can predict duration overrun, cost overrun and activities associated with any specific delay in highway construction projects. This tool utilizes simulation models as a knowledge base for generating the duration and cost overruns. The simulation models for duration and cost overruns of the project are developed based on the nature of the delay, activities associated with the delay and stochastic nature of the duration and cost overruns associated with the activities.

Keywords: cost, decision support tool, delay, probability, simulation.

INTRODUCTION

Development of highways is one of the main contribution factors in addition to sturdy communication lines for infrastructure development since highways act as arteries of national development. In the present system of scheduling construction projects, which utilizes critical path method (CPM) or project evaluation and review technique (PERT), the main input is duration for each activity. The activity duration is mainly dependent on site conditions that are unpredictable during the planning stage of the project. Hence, activities are delayed behind schedule or activity duration is overestimated such that an activity is likely to be completed ahead of the scheduled duration. Hence continuous site monitoring and updating of the schedule is necessary throughout the project to keep time and costs within reasonable limits.

Activity duration for any highway construction project is highly uncertain and this uncertainty is attributed to unprecedented events such as accidents, natural calamities, etc. or due to unexpected conditions such as financial problems, defective designs, corrections because of poor workmanship, etc. The duration overrun, which can occur in any construction project, may be due to one or more risk factors. The influence of each factor may vary with the activity depending on its nature, the accuracy of prediction and any corrective action taken by the project personnel.

[1] arun@bits-pilani.ac.in

Overrun in duration of an activity for any construction project is likely to affect the resources, which in turn affects costs associated with it. Overrun in duration is likely to augment project cost by unproductive manpower and equipment charges, the cost of additional resources for corrective actions, etc. Hence, cost overrun associated with the activity is directly related to duration overrun for the activity. Since duration overrun and cost overrun are interrelated, analysis of cost overrun is inevitable in the project schedule risk analysis.

In the present scenario, project monitoring is carried out by comparing the progress of individual activities and achievements of milestone completions with planned schedules. It is essential for the project management team to predict cost overrun based on various technical and non-technical problems associated with activities. However, cost estimates provide a baseline for assessment of financial performance. Hence, cost overrun is an indication of the influence of overrun risk factors on activities and in turn on the entire project. Project control procedures are mainly intended to identify deviations from project plans rather than suggest possible cost savings. Deviations from plans are likely to cause delay, which in turn result in cost overrun.

Predicting the influence of several parameters on a construction project is a rigorous process. The highway construction project is mostly influenced by more than one external parameter that can cause duration and cost overruns for the project. It is tedious for users to correlate various results from a simulation experiment to predict cost and duration and predict likely duration and cost overruns for the construction project. Hence, a decision support tool has been developed to predict and provide the result in a more realistic sense, which is more relevant to the real-world scenario so that decision makers can predict likely situations in construction sites under prevailing conditions. The decision support tool devised in this research provides duration and cost overruns associated with the probability of occurrence of risk factors provided by user.

DATA COLLECTION AND ANALYSIS

Schedule risk analysis is carried out depending on the nature of the risk and its influence on various activities. Data pertaining to duration and cost overruns of activities were collected from various construction project consultants and project engineers all over India. The data were collected with the aid of a questionnaire, which prompted them to provide duration and cost overruns of each activity in highway construction either in actual monetary value or as a percentage of the total cost. The questionnaire contained standard causes of delays that affect construction activities and activities that are affected by cause of delay. Out of one hundred and twenty questionnaires circulated among various field personnel, 64 responses were obtained. Based on the opinion of senior project implementation consultants in the highway construction sector of India, the main risk factors are categorized as:

- delay in land acquisition;
- obtaining statutory clearances;
- lack of infrastructure and outdated technology;
- delay in procuring materials and equipment;
- unexpected law and order problems;

- unexpected financial problems;
- failure of equipment or parts; and
- changes and correction in design.

The causes of delays are categorized into controllable and uncontrollable delay depending on the nature of the effect on activities. The controllable delays are those for which cause of delay can be predicted in advance and site personnel can take mitigation measures to reduce the effect on activities. Uncontrollable delays on the other hand cannot be predicted in advance and their effect on activities cannot be controlled. Hence depending on the cause of delay there are two sets of probability distribution function for cost and duration for each construction activity. Various causes of delay in the questionnaire, their nature and the activities affected are given in Table 1. This classification of risk is based on the opinions of various project execution consultants all over India. These data, obtained for the entire length of highway affected, are normalized for unit kilometre length for ease and uniform comparison between the projects. This is based on the assumption that the effect of highway construction activity is linearly uniform in nature. The overrun of activity cost and duration can be scaled up depending on the length of the highway affected by it.

These normalized data are analysed stochastically using BestFit 4.5 software developed by Palisade Inc. The software first analyses the data for the computation of the characteristic parameters of the data. Then the goodness of fit (GOF) test is conducted for 16 known standard distribution functions based on Kolmogrov–Smirinov (KS) and Anderson–Darling (AD) test. These tests determine the suitability of data of cost and duration overruns with the standard distribution function. The parameters of these distribution functions, viz. mean, mode, variance, shape parameter, etc. are then established by moment matching method. These standard probability distribution functions are then ranked based on root mean square error between percentile values of the fitted distribution and actual observations.

Table 1: Delay, nature and the affected activities

S.No	**Cause of delay**	**Nature of delay**	**Activities affected**
1.	Delay in land acquisition	Controllable	Site clearing, sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works
2.	Delay in obtaining statutory clearances	Controllable	Capping layer, sub-base course, road base course, base course, wearing course
3.	Lack of infrastructure	Uncontrollable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction
4.	Poor and outdated technology	Uncontrollable	
5.	Delay in the availability of design details	Controllable	Capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works
6.	Inefficiency in the design checks	Controllable	

7.	Delay in procuring materials	Uncontrollable	
8.	Delay in procuring equipment	Uncontrollable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction
9.	Rework due to improper quality control	Controllable	
10.	Improper planning for the supply of materials	Controllable	Capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction
11.	Poor coordination between contractors	Controllable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works
12.	Unexpected law and order problems in the site	Uncontrollable	
13.	Financial problems	Controllable	Site clearing, sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works
14.	Delay in interconnected activities	Uncontrollable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works
15.	Delay in payment and other capital facilities	Controllable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction
16.	Failure of equipment or parts	Uncontrollable	
17.	Changes in design	Controllable	Sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction
18.	Defects and correction in design	Controllable	Capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction

From this analysis it has been observed that duration overrun for controllable delay predominantly follows the gamma distribution function and the Erlang distribution function. However the Erlang distribution function is known to be one of the special cases of the gamma distribution function. Hence this can be idealized that duration overrun due to controllable delay follows the gamma distribution function. Similar analysis carried out in relation to cost overrun associated with the same nature of delay indicated that activities predominantly follow the beta distribution function. Distribution functions followed by various activities for both cost and duration overrun of due to a controllable delay are presented in Table 2.

Stochastic analysis was carried out for both activity costs and duration for uncontrollable delay. This analysis indicates duration overrun of the activities predominantly followed the Weibull and beta distribution functions while cost overrun did not show any converging trend to any of the standard distribution functions. Distribution functions followed by cost and duration overruns for each of the activities due to uncontrollable delays are presented in Table 3. Even though each activity followed a different distribution function for cost the majority of the activities followed the Weibull and beta distribution functions, which is evident from Table 2. Simulation models have been formulated based on probability distribution functions presented in Tables 2 and 3 for which the activities influenced by each cause of delay are obtained from Table 1.

Table 2: Probability distribution function for controllable delay

Activity	Duration	Cost
Clearing	Gamma (0.96, 1.87)	405 + 44600 × Beta (0.765, 1.48)
Sub-grade	7 × Beta (1.4, 3.29)	3120 + 205000 × Beta (0.595, 0.839)
Capping layer	Gamma (0.96, 1.87)	1020 + Exponential (113000)
Sub-base	Gamma (0.859, 2.03)	944 + Weibull (116000, 0.599)
Road base	Gamma (0.96, 1.87)	67 + 37400 × Beta (0.559, 0.96)
Base course	Gamma (0.941, 1.83)	232 + Gamma (150000, 0.6)
Wearing course	Erlang (0.996, 2)	3120 + Gamma (447000, 0.565)
C.D. foundation	Erlang (1.18, 2)	948 + 271000 × Beta (0.439, 0.759)
C.D. substructure	Erlang (1.18, 2)	948 + 271000 × Beta (0.439, 0.759)
C.D. superstructure	Erlang (1.18, 2)	948 + 271000 × Beta (0.439, 0.759)
Drainage	Erlang (1.07, 2)	313 + 215000 × Beta (0.485, 0.893)

Table 3: Probability distribution function for uncontrollable delays

Activity	Duration	Cost
Clearing	13 × Beta (0.819, 1.21)	299 + 177000 × Beta (0.416, 0.95)
Sub-grade	Weibull (5.28, 1.47)	299 + Exponential (84600)
Capping layer	9 × Beta (0.823, 1.26)	203 + Weibull (19600, 0.634)
Sub-base	Normal (4.5, 3.49)	188 + Gamma (58400, 0.465)
Road base	9 × Beta (0.783, 1.02)	13 + Exponential (4120)
Base course	9 × Beta (0.823, 1.26)	46 + Gamma (44000, 0.466)
Wearing course	9 × Beta (0.952, 1.3)	299 + Gamma (167000, 0.521)
C.D. foundation	Weibull (4.42, 1.25)	189 + Weibull (22900, 0.648)
C.D.substructure	Weibull (4.42, 1.25)	189 + Weibull (22900, 0.648)
C.D.superstructure	Weibull (4.42, 1.25)	189 + Weibull (22900, 0.648)
Drainage	Erlang (2.37, 2)	62 + Weibull (7460, 0.64)

SIMULATION MODELS

Simulation models are formulated separately for each cause of delay using the probability models for the cost and duration overruns of respective activities using Extend Simulation Software developed by Imagine That Inc. The simulation model formulated for each cause of delay is based on activities that are influenced by delay and the probability distribution function for cost and duration overruns for each of the activities based on the corresponding nature of delay. The project activities are represented by a set of attribute delay blocks connected in series and in parallel based on the relationship between activities. The entire system for project overrun is modelled using Generic library functions and Discrete Event library functions which are integrated in Extend Simulation software. A random number generator block is calibrated based on probability distribution functions of the duration overruns obtained for various activities. The probability associated with activity duration overrun is computed using equation blocks for each activity. Attribute delay block delays the entity leaving the block depending on random duration generated by the random number generator block which is devised to generate a random number according to the probability distribution function for that activity. Total project delay is computed using a set of equation blocks, which computes the total time for the entity to reach the end block through various network paths and takes the maximum time out of it.

The probability of duration overrun for each of the activities is computed with the aid of equation blocks with the corresponding equation of distribution function. This value is then used for computation of activity cost overrun using equation blocks using an inverse distribution function for the activity cost overrun in the next set of equation blocks. The total project cost overrun in each cycle is computed by adding up the activity cost overrun. The output of duration and cost overrun is recorded in text file ‘delay.txt’ as a two-dimensional matrix. The duration overrun, cost overrun and the corresponding confidence level are recorded along one row of the matrix with commas separating each field. This text file is used as dynamic knowledge base for the decision support tool. The simulation models for each cause of delay are different from each other in terms of nature and activities involved. As the simulation models can generate scenarios for unit kilometre of construction; a decision support tool has been developed based on the dynamic knowledge base of the simulation models to compute the risk associated with project schedules for any length of highway construction project.

KNOWLEDGE-BASED DECISION SUPPORT TOOL

A knowledge-based decision support tool (KBDST) is developed to provide project personnel with a handy tool to evaluate risk associated with delays in highway construction projects for which the flowchart is presented in Figure 1. KBDST is developed in Java with the aid of simulation models to generate a dynamic knowledge base for cost and duration overruns for the highway construction project. Java 1.3 has been adopted for the development of the expert system, as it is independent of the operating system and can integrate other commercial software very easily. The user is prompted to select the cause of delay to run a corresponding simulation model by selecting one of the predefined causes of delay from the ComboList provided in the interface, which then selects and runs the appropriate overrun simulation model. The system was tested with a user-defined risk factor of ‘delay in land acquisition’ with a confidence level of 92% for a 6km stretch of highway. The tool is programmed to select the appropriate simulation model, which has controllable nature and affects corresponding activities, viz. site clearing, sub-grade, capping layer, sub-base course, road base course, base course, wearing course, cross-drainage construction, drainage and miscellaneous works When predefined 10 000 simulation runs were over the user was prompted to provide the system with the length of highway affected by delay and the level of uncertainty associated with the delay through JText fields provided in interface.

KBDST checks the appropriate column representing probability in the text file ‘delay.txt’ generated by the simulation model, for the value of confidence level provided by the user. It then reads the corresponding row of the matching probability for the duration and cost overrun from the first and second fields respectively. These values are then interpolated linearly for the entire length of highway affected which is input presented by the user. KBDST outputs duration and cost overruns for the entire stretch of highway affected by it at the known level of uncertainty along with activities affected by the delay in the JText fields, which pops up in result window in the interface.

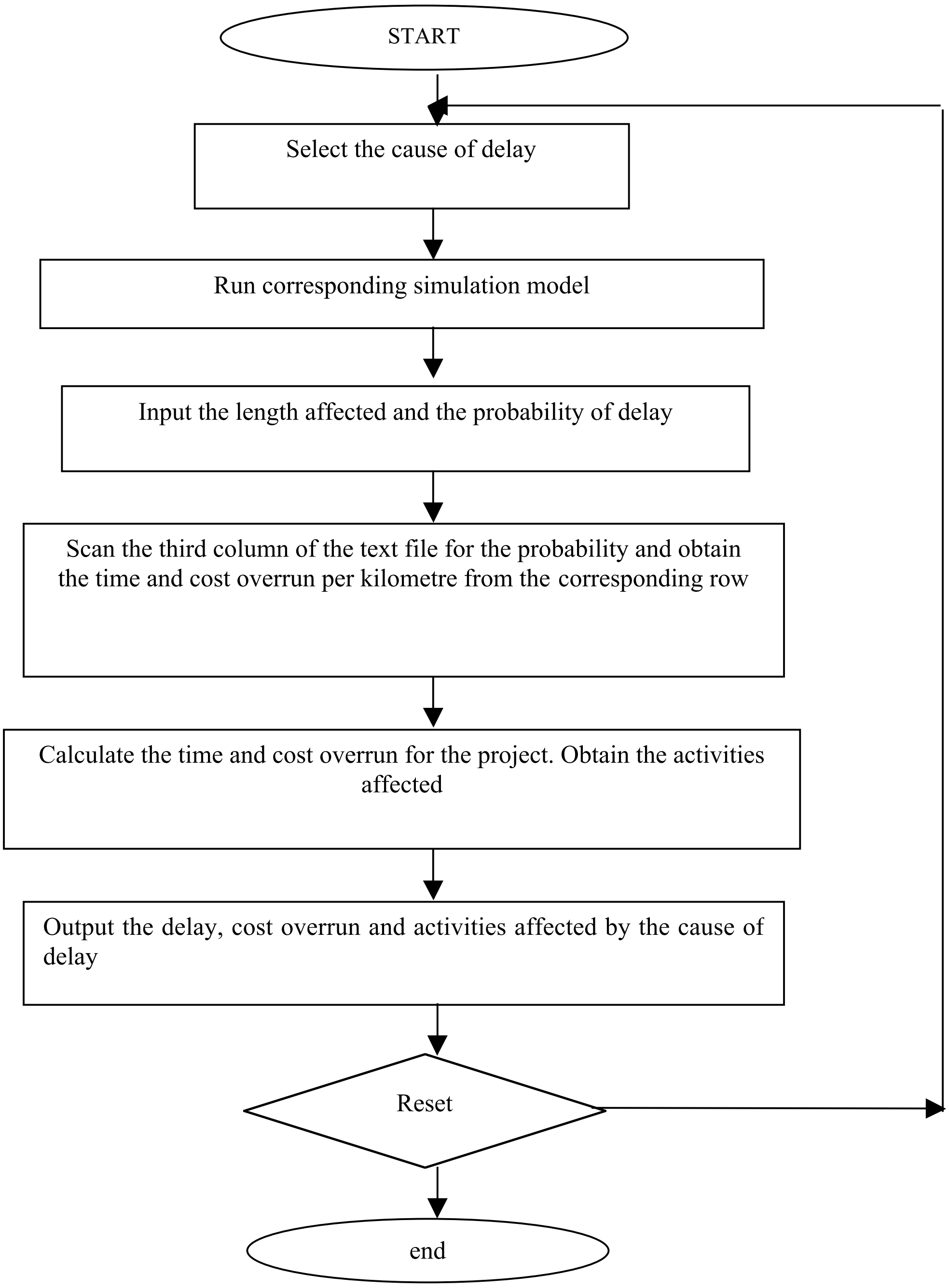


Figure 1: Flowchart of KBDST

DISCUSSION AND CONCLUSIONS

KBDST aids project personnel to evaluate the risks involved in the project in terms of duration as well as cost with known levels of uncertainty. It also provides the user with activities that are affected by any particular risk factor. Hence it provides a hand tool for project managers to monitor and control the activities and predict the activities that are likely to influence the cost. KBDST is designed with the aid of delay analysis simulation model for unit length of highway and the software scales up duration and cost overrun for any length of the highway affected depending on the input provided by the user. The scaling up of the overrun is based on the assumption that cost and overrun for the activities as well as the project are linear in nature. However this assumption may not hold good in all cases of highway construction projects as overrun in duration may decrease with increase in length of project due to corrective actions taken in subsequent stretches. However, the delay analysis is carried out based on actual probability distribution functions followed by activities in highway construction projects rather than assuming a probability distribution function. The validation was carried out using various completed projects and had indicated more than 80% accuracy in predicting the overrun. On condition of anonymity, it was revealed that one 6km stretch of an expressway project in India had incurred a cost overrun and duration overrun of 83.5 lakh Indian Rupees and six months respectively due to ‘delay in land acquisition’. The output of KBDST indicated a duration overrun of 185 days and a cost overrun of 8 334 674 Indian Rupees at 92% confidence level. This study can be extended to other types of construction project and a more realistic risk analysis can be carried out. However, this study can be enhanced by taking into account the interrelation of various risk factors that affect highway construction schedules and by dividing the activities into sub-activities, viz. the cross-drainage works need to be studied separately as this factor is peculiar based on cost and duration aspects.

REFERENCES

AbouRizk, S M and Halpin, D W (1992) Statistical properties of construction duration data. *ASCE Journal of Construction Engineering and Management*, **118**(3), 525–44.

Arun, C (2003) *Development of decisions support tool for scheduling highway construction projects based on simulation models*, Published PhD Thesis, College of Engineering, Guindy, Anna University, India.

Arun, C and Nagabhushana, Rao Bh (2003) Probability models for highway construction activities in India. Paper presented at the Ninth East Asia Pacific Conference on Structural Engineering and Construction, Bali, Indonesia, 16–18 December 2003.

Barraza, G A, Back, W E and Mata, F (2000) Probabilistic monitoring of project performance using SS curves. *ASCE Journal of Construction Engineering and Management*, **126**(2), 142–8.

Beeston, D T (1983) *Statistical methods for building price data*. London: E & F N Spon.

Bubshait, A A and Cunningham, M J (1998) Comparison of delay analysis methodologies. *ASCE Journal of Construction Engineering and Management*, **124**(4), 315–22.

Fente, J, Schexnayder, C and Knutson, K (2000) Defining a probability distribution function for construction simulation. *ASCE Journal of Construction Engineering and Management*, **126**(3), 234–41.

Howick, S and Eden, C (2001) The impact of disruption and delay when compressing large projects: going for incentives? *Journal of Operations Research Society*, **52**, 26–34.

Hulett, D T (1996) Schedule risk analysis simplified. *P M Network*, **10**(7), 25–32.

Law, A M and Kelton, W D (2000) *Simulation modelling and analysis.* New York: McGraw-Hill Inc.

Lee, D-E and Arditi, D (2006) Automated statistical analysis in stochastic project scheduling simulation. *ASCE Journal of Construction Engineering and Management*, **132**(3), 268–77.

Oliveros, A V O and Fayek, A R (2005) Fuzzy logic approach for activity delay analysis and schedule updating. *ASCE Journal of Construction Engineering and Management*, **131**(1), 42–51.

Shi, J J, Cheung, S O and Arditi, D (2001) Construction delay computation method. *ASCE Journal of Construction Engineering and Management*, **127**(1), 60–5.

Zhang, H, Shi, J and Tam, C M (2002) Application of simulation related techniques to construction operations. *Engineering Construction and Architectural Management*, **4**(5–6), 433–45.

APPENDIX I

Distributions	Probability distribution function
Erlang	$f(\beta, m) = \frac{1}{\beta(m-1)!}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\frac{x}{\beta}}$ m > 0 (integer shape parameter) β > 0 (continuous scale parameter)
Gamma	$f(\beta, \alpha) = \frac{1}{\beta.\Gamma_{(\alpha)}}\left(\frac{x}{\beta}\right)^{\alpha-1} e^{-\frac{x}{\beta}}$ α > 0 (scale parameter) β > 0 (shape parameter)
Weibull	$f(\beta, \alpha) = \frac{\alpha.x^{\alpha-1}}{\beta^{\alpha}} e^{-\left(\frac{x}{\beta}\right)^{\alpha}}$ α > 0 (scale parameter) β > 0 (shape parameter)
Beta	$f(\alpha, \beta) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha, \beta)}$ α > 0 (shape parameter) β > 0 (shape parameter) B is beta function
Normal	$f(\mu, \sigma) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$ μ = mean of the distribution σ > 0 (standard deviation)

APPENDIX II

Questionnaire survey (delay/cost overrun)

Project name:

Project status: (ongoing/completed)

Length of highway/chainages: Proposed year of completion

Planned duration: Actual duration:

S.No	Reason	Site clearance	Sub-grade	Cross-drainage works	Capping layer	Sub-base course	Road base course	Base course	Wearing course	Drains and misc	Commissioning.
1.	Delay in land acquisition										
2.	Delay in obtaining statutory clearances										
3.	Lack of infrastructure										
4.	Poor and outdated technology										
5.	Delay in the availability of design details										
6.	Inefficiency in the design checks										
7.	Delay in procuring materials										
8.	Delay in procuring equipment										
9.	Rework due to improper quality control										
10.	Improper planning for the supply of materials										
11.	Poor coordination between contractors										
12.	Unexpected law and order problems in the site										
13.	Financial problems										
14.	Delay in interconnected activities										
15.	Delay in site clearance										
16.	Delay in payment and other capital facilities										
17.	Failure of equipment or parts										
18.	Changes in design										
19.	Defects and correction is design										
20.	Managerial problems										
21.	Other problems (list below if any)										

GENERAL SYSTEMS PERSPECTIVE ON ACHIEVING CONTINUOUS SYNERGY IN A PROJECT ORGANIZATION

Milan Radosavljevic[1]

School of Construction Management and Engineering, University of Reading, Whiteknights, PO Box 219, Reading, RG6 6AW, UK

Studies of construction labour productivity have revealed that limited predictability and multi-agent social complexity make long-range planning of construction projects extremely inaccurate. Fire-fighting, a cultural feature of construction project management, social and structural diversity of involved permanent organizations, and structural temporality all contribute towards relational failures and frequent changes. The main purpose of this paper is therefore to demonstrate that appropriate construction planning may have a profound synergistic effect on structural integration of a project organization. Using the general systems theory perspective, it is further a specific objective to investigate and evaluate organizational effects of changes in planning and potentials for achieving continuous project-organizational synergy. The newly developed methodology recognizes that planning should also represent a continuous, improvement-leading driving force throughout a project. The synergistic effect of the process planning membership duality fostered project-wide integration, eliminated internal boundaries, and created a pool of constantly upgrading knowledge. It maintained a creative environment that resulted in a number of process-related improvements from all parts of the organization. As a result, labour productivity has seen increases of more than 30%, profits have risen from an average of 12% to more than 18%, and project durations have been reduced by several days.

Keywords: construction planning, off-site production, organizational effectiveness, project organization, systems theory.

INTRODUCTION

Project-organizational efficiency

It appears that construction project management has landed in an unenviable position. Projects are becoming more complex, clients more demanding and the market is offering a variety of materials that demand a highly-skilled and professional labour-force. On the other hand, the technology has improved and hence more efficient and positive progress would be expected. There is actually plenty of literature on productivity, methods for measuring productivity, improvements of productivity, factors affecting productivity, etc (Harris *et al*. 2006; Thomas and Završki 1999; Jayawardane *et al*. 1995; Luxhoj *et al*. 1990). Why is it then that, with all the research going on and the new, more efficient equipment to hand, the construction industry has not managed to improve its efficiency considerably? It seems that by mostly concentrating on productivity and on-site management-related issues, construction management research is trying to suppress problems rather than define real causes for

[1] m.radosavljevic@reading.ac.uk

organizational efficiency/inefficiency. Other reasons are complexity and uniqueness of construction projects (Proverbs *et al*. 1998, 1999; Bertelsen 2003). Approach that resulted in higher efficiency in one project may prove totally inappropriate in others.

Projects clearly vary in their efficiency but it remains unclear as to what makes some of them more efficient than others. However, it is clear that project organizations are social systems characterized by their temporal existence at the intersection of various, often very different, permanent organizations (Asheim 2002; Lundin and Söderholm 1995). That being the case, it then must be possible to determine organizational efficiency parameters.

Synergy

One of the most useful organizational efficiency parameter stems from a general systems perspective of social organizations. According to general systems theorists all systems consist of components and relations of interactions between them (Scott 1987; Kajzer 1982; Mesarovic and Takahara 1975; Bertalanffy 1950). They recognize social systems as open systems of relations because they interact with other social systems and their environment. Furthermore, social systems may be constituted by components, themselves being social systems, so they can be viewed as systems of *n*-th order. They are created and recreated through two diametrically opposing processes: *folding* and *composing*. While folding represents a simple sum of components and relations without any changes in the quality of relations and components, composing represents a sum that establishes new relations bringing new quality to a higher order system. The qualitative difference between a composed higher order system and the sum of qualities of “old” sub-systems is thus called synergy. Unfortunately, synergy is often viewed only in relation to frequently unsuccessful corporate mergers making it an unpopular term (Chatterjee 2007). Synergy, however, can also appear within organizations as a consequence of local and global fitness optimization (Dooley 1996). Nevertheless, synergistic effects within organizations are still hugely neglected.

In construction, although not referring to synergy, Dubois and Gadde (2001) address its negative side by viewing construction process as a loosely coupled system. Such a system is disintegrated as soon as one project is complete, and re-established in a different way as soon as a new one has started making coordination and learning repeatedly ineffective. However, synergy within construction project organizations has not yet been addressed appropriately, even though they in many aspects resemble merger situations where synergistic effects have already been extensively analysed (Hitt *et al*. 2001).

Problems, aims and objectives

Cultural clashes, potential issues of mistrust and organizational incompatibility are all difficulties that threat both mergers and construction project organizations. It is therefore of vital importance to be able to appropriately model temporary construction project organizations and their constitutive permanent organizations in order to investigate internal synergistic effects. In light of such understanding, this study aims at uncovering evidence of a continuous synergy in a project organization with the following specific objectives:

- To present systems interpretation of the so called Process Planning Methodology (PPM), a newly adopted short-term planning process in the off-site construction projects that triggers a continuous process of internal re-composition.

- To present relational differences between a traditional approach to managing such projects and the newly established approach.
- To identify potentials for assessing qualitative difference in relations within a continuously recomposed organization.

DATA AND METHODOLOGY

The core of the study is an off-site project in Slovenia that was divided into two separate sub-projects. The PPM was applied to one of the sub-projects by applying a double-loop framework. The other sub-project was managed using firm's traditional project management approach. It is worthwhile mentioning at this point that off-site projects in Slovenia are not characterized by a very distinctive project organization. They are mostly managed through heavy reliance on main contractor's internal organizational structure. This is the main reason why both project and firm organizations are discussed intertwiningly from this point forward.

The details of the PPM, its framework, necessary constitutive elements and application are not relevant here and have been, nonetheless, extensively covered elsewhere (Radosavljevic 2005; Radosavljevic and Horner 2007). Therefore, according to the above objective, this study is to create a theoretical explanation of the organizational restructuring that occurred after the PPM was fully in place.

The mathematics of achieved continuous organizational re-composition, presented according to the systems theory, forms a major part of the methodology and follows the work of Kajzer (1982), and Mesarovic and Takahara (1975). This was found to be the only analytical approach that could be used in order to illustrate these relational changes.

SYSTEMS PERSPECTIVE

Traditional project management

One of the sub-projects was managed traditionally where firm's project managers, although being responsible for a number of projects, were operationally intertwined in the firm's hierarchy. All off-site construction projects thus required full commitment of firm's departmental directors (i.e. purchasing, R&D, quarries, production units, etc.). These are responsible for managing supporting activities like logistics, material testing, supplies, etc. The traditional approach normally resulted in delays due to seemingly unknown reasons and poor relations within project and firm organizations. Project delivery was regularly under pressure due to disputes and power clashes between various directors and project managers. The systems view of the firm organization reveals major reasons for often unsatisfactory project delivery. Figure 1 shows that departments may be subject to four types of boundary relations, namely managerial, interdepartmental, inter-level and external relations. Boundary relations can be further split into internal (between sub-systems) and external boundary relations (between sub-systems and the environment):

$$BR_i^{(n-1)} = IBR_i^{(n-1)} + EBR_i^{(n-1)} \tag{1}$$

where,

$IBR_i^{(n-1)}$ internal boundary relations of constituent sub-systems in a system of *n*-th order

$EBR_i^{(n-1)}$ external boundary relations of constituent sub-systems in a system of *n*-th order

Equations 2 and 3 show that internal boundary relations between sub-systems (level *n-1*) represent relations within an organization so they can be called system relations at the *n*-th level. Clearly, it is of interest to organizations to maximize internal relations in order to improve communication. This can only be improved through an increase of internal system relations (i.e. relations between sub-systems).

$$SR^{(n)} = \bigcup_{i=1}^{m} \bigcup_{j=1}^{m} \left(BR_i^{(n-1)} \cap BR_j^{(n-1)} \right); \quad i \neq j \tag{2}$$

$$SR^{(n)} = IBR_i^{(n-1)} \tag{3}$$

However, this tendency towards better communication goes on account of external relations, making highly hierarchical and departmentalized organizations alienated from their environment (Levinthal 1991; Child 1984). Because boundary relations consist of internal boundary relations (system relations) and external boundary relations, one can maximize system relations only to the detriment of external boundary relations. In other words, maximizing system relations minimizes external relations (see Equations 4, 5 and 6).

$$IBR_i^{(n-1)} = BR_i^{(n-1)} - EBR_i^{(n-1)} \tag{4}$$

$$SR^{(n)} = BR_i^{(n-1)} - EBR_i^{(n-1)} \tag{5}$$

$$SR_{\max}^{(n)} = IBR_i^{(n-1)}; EBR_i^{(n-1)} \to \emptyset \tag{6}$$

where,

$IBR_i^{(n-1)}$ internal boundary relations of the constituent sub-systems

$EBR_i^{(n-1)}$ external boundary relations of the constituent sub-systems

$SR_{max}^{(n)}$ maximized system relations at the *n*th level.

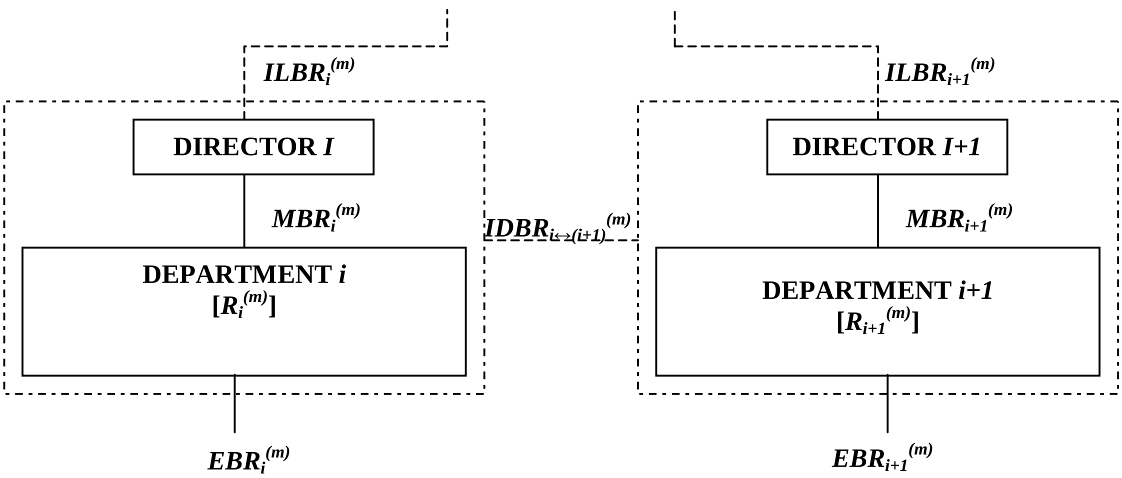


Figure 1: Relations of interactions within departments at m-th level ($R_i^{(m)}$ represents internal relations in i-th department; $MBR_i^{(m)}$ represents managerial boundary relations; $IDBR_{i\leftrightarrow(i+1)}^{(m)}$

represents interdepartmental boundary relations; $ILBR_i^{(m)}$ represents inter-level boundary relations and $EBR_i^{(m)}$ represents external boundary relations

With a rising number of levels and departments, external relations become restricted to only a limited number of people, making organizational adaptability to external changes extremely difficult (Robbins 1998; Pugh 1997). They become prescribed within bureaucratic rules hindering individual participation and initiatives (Torrington and Hall 1998). Furthermore, maximizing system relations necessarily deteriorates creativity of human beings by restricting their possible interactions outside the prescribed ones.

The organization of the traditionally managed sub-project suffered significantly due to these problems. On top of issues within the project organization, the project manager had to deal with obstacles internal to the firm. This was also claimed to be the main reason for frequent fire-fighting and a lack of time.

Process planning methodology
The second sub-project was managed using the so-called process planning methodology by dividing it into several week-long sub-processes. A process is here defined as a sum of successfully accomplished activities, which are interconnected by a specific logic of order to represent a functional totality. The PPM relies on improved definition of planning, a process planning group and two iterative improvement loops but a much more detailed description of the case study can be found elsewhere (Radosavljevic and Horner 2007).

Interestingly, the new planning methodology changed the operational structure of the firm's organization. It has become project-centred with a control group having a major and fluctuating position between emerging *Greater production* and *Greater management* sub-systems (see Figure 2). This is probably one of the reasons that even traditionally managed sub-project was completed within budget and on time.

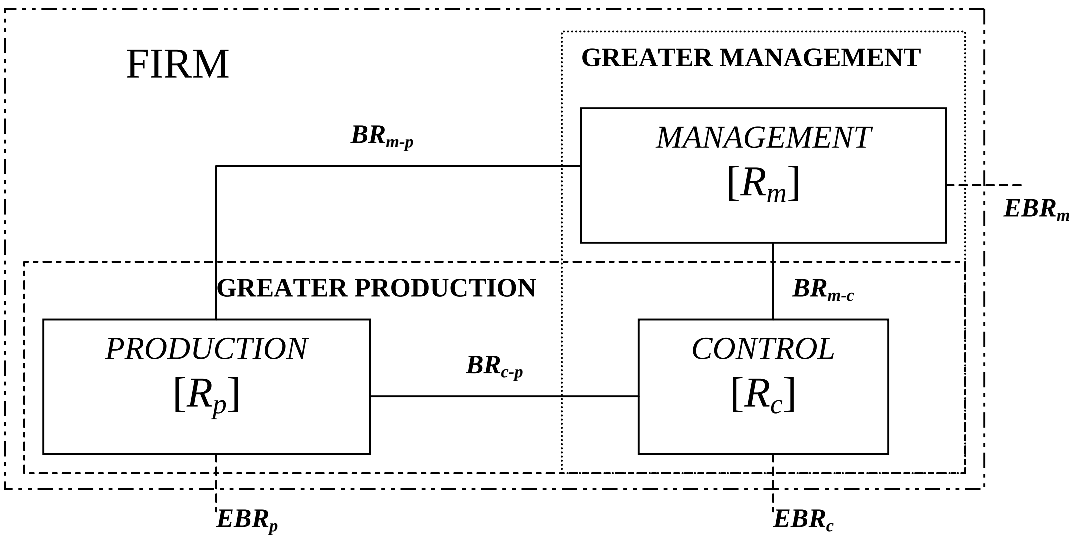


Figure 2: PPM-induced relations of interactions that only divide a firm into three functionally different sub-systems (production, control and management).

In the above declaration, *Management* involves all those managers that, unlike the control group, do not participate in production. In the similar note, *Production* consists of all production workers that do not participate in management. The control group is thus a dynamic link between *Management* and *Production*. Because of its alternating participation in production and management, *Production* with *Control* represents the *Greater production* sub-system and *Management* with *Control* represents the *Greater management* sub-system. The dynamic characteristic of *Control* as a constituent category of both *Greater production* and *Greater management* sub-systems plays a mediatory role between *Production* and *Management*. The question is why boundaries between *Production* and *Control* and between *Management* and *Control* are not so called "real" internal boundaries? What, then, is a major difference between the managerial boundary relations from Figure 1 and these relations? The essential point is that the boundary between departments and the managerial sub-system prevents direct participation of departmental members in the activities of the managerial sub-system which consequently diminishes individual initiative (Torrington and Hall 1998). Members of *Control*, on the other hand, participate in the activities of both *Greater management* and *Greater production* sub-systems (everyday work). The *Control* sub-system participates in the *Greater production* and *Greater management* sub-systems and is not isolated from them. They actively participate in all activities within *Greater management* due to the feedback they receive from *Production* and they also facilitate managers to modify their decisions according to what is happening in the production. Their position within organizational structure is equal to any other (positions are not hierarchically differentiated). They also actively participate in *Greater Production* because their role is to implement agreed activities. Members of *Production*, due to their participation in the production, usually cannot fully participate in process planning and, on the other hand, members of *Management* most of the time cannot be present and operationally do not participate in production. This is the only "pure" internal boundary in this case. It is equivalent to the ones between departments and different levels, but such a boundary is physically and functionally indispensable.

$$R_p^{(1)} \cap R_m^{(1)} = \emptyset \qquad (7)$$

Management and *Production* are two operationally separate sub-systems that do not share common internal system relations (see Equation 7). *Control* is a first order sub-system that is subject to a dynamic membership by being a constitutive element of both second order sub-systems. This is a unique property that enables a continuous process of decomposition and re-composition. Firstly, members of a control sub-system participate in the production by gathering knowledge about the processes of production, accompanying difficulties and possible solutions that might be revealed by observing the processes. When the *Control* members participate in the process planning, they trigger composition of the *Greater management* sub-system and decomposition of the *Greater production* sub-system. During the process of composition, they bring in new relations enriched by gathered knowledge from *Greater production* and help to bring up ideas for enhancing the process of production. They move back on a daily basis and recompose the *Greater production* sub-system by bringing in iteratively derived instructions for the planned processes of production. Such iterative and dynamic processes of re-composition and decomposition are necessary and, regardless of the level, create changes in relations within all sub-systems. The most significant changes appear among the internal boundary relations that are now split into two new categories, pure and seemingly boundary relations, in the following way:

$$\sum_{j=1}^{2} SR_{j*}^{(2)} = \sum_{j=1}^{2} R_{j*}^{(2)} - \left[\sum_{i=1}^{3} R_{i*}^{(1)} \right] = \sum_{i=1}^{3} IBR_{i*}^{''(1)} \tag{8}$$

where

$$\sum_{i=1}^{3} IBR_{i*}^{''(1)} = IBR_{i*}^{'(1)} + IBR_{i*}^{(1)} = BR_{C\leftrightarrow M}^{'(1)} + BR_{C\leftrightarrow P}^{'(1)} + BR_{P\leftrightarrow M}^{(1)} \tag{9}$$

$$IBR_{i*}^{(1)} = BR_{P\leftrightarrow M}^{(1)} \tag{10}$$

where

$IBR_{i*}^{''(1)}$	all boundary relations (real and seemingly) of *i-th* first order sub-system
$SR_{*j}^{(2)}$	system relations within greater management (*j=1*) or greater production (*j=2*) second order sub-system
$R_{*j}^{(2)}$	internal relations within greater management (*j=1*) or greater production (*j=2*) second order sub-system
$R_{i*}^{(1)}$	internal relations of *i-th* first order sub-system
$IBR_{i*}^{'(1)}$	internal seemingly boundary relations of *i-th* first order sub-system
$BR_{C\leftrightarrow M}^{'(1)}$	seemingly boundary relations between control and pure management
$BR_{C\leftrightarrow P}^{'(1)}$	seemingly boundary relations between control and pure production
$BR_{M\leftrightarrow P}^{'(1)}$	boundary relations between pure management and pure production
$IBR_{i*}^{(1)}$	"real" internal boundary relations of *i-th* first order sub-system.

If we now consider the above dynamic participation of *Control* in the relational domain of both the second order sub-systems and take in the account Equation 9, then boundary relations between *Control* and *Management*, and between *Control* and *Production* are clearly not "real" boundary relations. This is so because of iterative internal relational activity within both second order sub-systems, which these seemingly boundary relations depend on and can be expressed in the following way:

$$BR_{*(C\leftrightarrow M)j}^{'(1)} = f\left(R_{*(C\leftrightarrow P)j}^{(2)}\right); \quad j = 1,2,\ldots,\infty \tag{11}$$

$$BR_{*(C\leftrightarrow P)j}^{'(1)} = f\left(R_{*(C\leftrightarrow M)l-1}^{(2)}\right); \quad l = 2,3,\ldots,\infty \tag{12}$$

where

$R_{*(C\leftrightarrow P)j}^{(2)}$	internal relations within greater production in *j-th* participation of the control sub-system
$R_{*(C\leftrightarrow M)l-1}^{(2)}$	internal relations within greater management in *(l-1)-st* participation of the control sub-system.

Moreover, the system relations within *Greater Management* and *Greater Production*, constituted by the internal boundary relations of their integrands, can entirely depend on these seemingly boundary relations. Even if "real" boundary relations between *Production* and *Management* are halted, a firm would still preserve its operational activity and would not disintegrate, which can be shown by:

$$\coprod_{j=1}^{2} SR_{*j}^{(2)} = BR_{*C \leftrightarrow M}^{'(1)} + BR_{*C \leftrightarrow P}^{'(1)}; \quad BR_{*P \leftrightarrow M}^{(1)} \rightarrow \emptyset \tag{13}$$

In other words, pure internal boundary relations are not necessary conditions for the functioning of such an organization. All sub-systems (regardless the level) can therefore maintain an equability of relations with the external environment. The firm can continuously absorb external project level or market level disturbances and subordinate them to the maintenance of their integral organization. Such unrestricted equability takes place with no harm to the system relations (see Equation 13). Furthermore, by implementing the PPM, *Greater Management*, in this manner, deliberately incorporates components of systems operationally outside of a firm, such as a number of clients and designers' representatives.

The synergistic effect of the continuous membership duality fosters project-wide integration, eliminates the need for internal boundaries, and creates a pool of constantly upgrading knowledge. In the above case, it maintained a creative environment that resulted in a number of process-related improvements coming from all parts of the organization.

Continuous synergy in the PPM

Continuous re-composition, experienced in the PPM-managed sub-project, is hence a process that continuously regenerates involved sub-systems, with new characteristics. In the similar way, by regenerating sub-systems, it also changes quality of the constituent components. The composition **C** of *Greater Management* and *Greater Production* second order sub-systems can be expressed in the following way:

$$S_*^{(2)} = \mathbf{C}_{i=1}^{m} S_i^{(1)} \tag{14}$$

so that:

$$S_*^{(2)} = S_*^{(2)}\left(C^{(2)}, R_*^{(2)}, BR_*^{(2)}\right) \tag{15}$$

where

$S_*^{(2)}$ new system of the second order

$C^{(2)}$ set of components of the second order system (they obviously do not change)

$R_*^{(2)}$ changed set of internal relations in the second order system

$BR_*^{(2)}$ changed set of boundary relations in the second order system.

In this manner, for an *n*-th order system $S^{(n)}$ Kajzer (1982) determines composability as a measure of quality $q_i^{(n)}$:

$$S^{(1)} = \left\{\left(S_i^{(1)}, q_i^{(1)}\right); \quad i \in I\right\} \tag{16}$$

The quality of the second order system in Equation 14 is therefore different from the sum of qualities of its first-order sub-systems before the composition. This difference of the sum before and the resulting second order system after the composition is called synergy. However, synergy is only suitable if it brings new, better quality in relations, which can be expressed as follows:

$$q^{(2)} > \sum_{j \in J} q_j^{(1)} \tag{17}$$

This is a necessary condition for composability but not sufficient because one may increase the quality of the original systems without composing them. The process of continuous re-composition yields a set of compounds of the second order system $S_i^{(2)}$ with its related measures of quality $q_{ip}^{(2)}$:

$$S_i^{(2)} = \left\{ \left(S_{ip}^{(2)}, q_{ip}^{(2)} \right); p = 1,2,...q \right\}; \quad i \in I \tag{18}$$

It is hoped that an iterative process will yield optimal possible quality $q_{io}^{(2)}$ after every iteration in the following way:

$$q_{i0}^{(2)} = \max \left\lfloor q_{ip}^{(2)} \right\rfloor; \quad i \in I; \quad p = 1,2,...,q \tag{19}$$

with a qualitative leap $\rho_i^{(2)}$:

$$\rho_i^{(2)} = q_{i0}^{(2)} - q_i^{(2)}; \quad i \in I \tag{20}$$

This qualitative leap is a positive synergy that the PPM hoped to achieve after every *Control* membership iteration. Quantifying synergistic effects in such a way is not yet possible and future research will be needed. However, final results were very promising. The PPM-managed sub-project resulted in an increase of labour productivity by more than 30%, profits rose from an average of 12% to more than 18%, and the project duration has been reduced by three days (Radosavljevic and Horner 2007).

CONCLUSIONS

Although problems of hierarchical departmentalization have been well documented, no studies have been found that would produce a generic underlying theory. The aim of this research was therefore to uncover evidence of a continuous synergy in the PPM-based project organization that, in the case of the firm under study, was intertwined with the firm’s organization.

The mathematical general systems perspective of the traditional and PPM-based sub-systems reveals important and as yet unanalysed relational differences. Changed planning methodology has had a profound effect on how the firm has operated. While departmentalized structure relies on increased internal system relations that diminish its ability to effectively relate with the external environment, PPM through its *Control* sub-system establishes a dynamic link between *Production* and *Management* that enables external adaptability. Although experienced in practice, this huge difference was only truly depicted with the general systems theory.

The importance of this perspective is obvious. It enabled the firm to investigate relational weaknesses in the organization and it also exhibits great potentials for the pre-analysis of organizational compositions regardless of the organizational structure. General systems theory thus provides a vehicle for understanding relational differences between different organizational settings.

The most important message of this particular research is thus not the improvements achieved through the implementation of the new approach *per se*. What really matters is the ability to explain major differences between the traditional and this new approach. General systems theory provides a generic mathematical approach to scrutinize organizations and reveals why some of them are more successful than others.

REFERENCES

Asheim, B T (2002) Temporary organisations and spatial embeddedness of learning and knowledge creation. *Geografiska Annaler B*, **84**(2), 111–24.

Bertalanffy, L von (1950) The theory of open systems in physics and biology. *Science*, **3**(1), 23–9.

Chatterjee, S (2007) Why is synergy so difficult in mergers of related businesses? *Strategy & Leadership*, **35**(2), 46–52.

Child, J (1984) *Organization: A guide to problems and practice*. Harper & Row.

Dooley, K (1996) A nominal definition of complex adaptive systems. *The chaos network*, **8**(1), 2–3.

Dubois, A and Gadde, L-E (2001) The construction industry as a loosely coupled system – Implications for productivity and innovativity. *In: Proceedings, 17th Annual IMP Conference*, 9–11 September 2001, Oslo, Norway.

Harris, F, McCaffer, R and Edum-Fotwe, F (2006) *Modern construction management.* Oxford: Blackwell Publishing.

Hitt, M A, Harrison, J S and Ireland, R D (2001) *Mergers & acquisitions: a guide to creating value for stakeholders*. Oxford: Oxford University Press.

Jayawardane, A K W, Price, A D F and Harris, F C (1995) Measurement of brickwork and blockwork productivity: Part A. *Building research and information*, **23**(2) 147–55.

Kajzer, Š (1982) *Istraživanje strukture i kompozicije mikroekonomskih sistema u udruženom radu*, Unpublished PhD thesis, Faculty of Economics, University of Zagreb.

Levinthal, D A (1991) Organizational adaptation and environmental selection – Interrelated processes of change. *Organization Science*, **2**(1), 140–45.

Lundin, R A and Söderholm A (1995) A theory of the temporary organization, *Scandinavian Journal of Management*, **11**(4), 437–55.

Luxhoj, J T and Tao P-C (1990) Measuring the Productivity of Construction Maintenance Operations. *Journal - American Water Works Association*, **82**(8), 35–9.

Mesarovic, M D and Takahara, Y (1975) *General systems theory: Mathematical foundations*. Academic Press Inc.

Proverbs, D G, Holt, G D and Olomolaiye, P O (1999) Factors impacting construction project duration: A comparison between France, Germany and the UK. *Building and Environment*, **34**(2), 197–204.

Pugh, D S (1997) *Organisation theory*, *Selected reading*. 4ed. Harmondsworth: Penguin Books.

Radosavljevic, M (2005) The process based short-term planning methodology as a tool for maintaining knowledge sustainability in the construction industry. *In:* F L Ribeiro *et al*. (Eds.), *2nd Annual CIBW102 Conference*, 19–20 May 2005, Lisbon, Portugal.

Radosavljevic, M and Horner, R M W (2007) Process planning methodology: dynamic short-term planning for off-site construction in Slovenia. *Construction Management and Economics*, **25**(2), 143–56.

Robbins, S P (1998) *Organisational behaviour*. 8ed. Prentice-Hall International Inc.

Scott, W R (1987) *Organisations: Rational, natural, and open systems*. 2ed. Prentice-Hall International editions.

Thomas, H R and Završki, I (1999) Construction Baseline Productivity: Theory and Practice. *Journal of Construction Engineering and Management*, **125**(5), 295–303.

Torrington, D and Hall, L (1998) *Human resource management*. London: Prentice Hall Europe.

PSYCHO-SOCIAL APPROACH FOR DISCERNING THE DICHOTOMY OF COMPETITION AND COLLABORATION TO ADVANCE MUTUALISTIC RELATIONSHIPS IN CONSTRUCTION

Abbas Ali Elmualim[1]

Innovative Construction Research Centre, The School of Construction Management and Engineering, The University of Reading, RG6 6AW, UK

Construction is largely viewed as a fragmented industry. Such fragmentation is due to the various cultural values, processes and interests of diverse participating organizations in project delivery. The industry is further viewed as being of low trust with competitive and adversarial relationships as the dominant strand of its culture. A theoretical critique of competitive and collaborative attitudes pertinent within the construction industry is reviewed. This critique reviews the rhetoric of collaboration in the UK construction industry. The critique is further extended to draw distinctions between psycho-structural and the socio-structural dimensions of culture to investigate and evaluate cultural changes and adaptations. This is in addition to understanding power distribution and its influence on competitive or collaborative attitudes. This is vital in order to understand the underpinning rationale behind adversarial and mutualistic models of behaviour through their manifestations within the construction industry's managerial practices. This psycho and socio structural approach advocates the paramount advantages of mutualistic management practices for a diverse/fragmented industry such as construction depicting various schools of thoughts, which include communication theory, system thinking, feminism, and environmental groups.

Keywords: adversarial behaviour, collaboration, competitiveness, culture and mutualism.

INTRODUCTION

The construction industry is widely viewed as a fragmented and diverse industry due to its project based nature. According to Wild (2002), 80% of construction projects involve a one-off clients and are non-recurrent. There is mounting pressure for construction to collaborate. The discourse of change towards collaboration espouses an improvement in contracts, communications and management (Egan 1998). The recommended change remains an aspiration of the policy makers (Wild 2002). The inception, design, construction and operation of any construction project require the participation of various agents according to their professional knowledge, experience and their required input into the specific project. By nature, the diverse number of participants in construction and the delivery of projects require collaboration by these participants. However, each constituency of participants has its own agenda and interests, and mobilizes its resources, knowledge and practices as part of the project to meet its interests. These interests are mainly financial to achieve a competitive edge of their competitors (Elmualim *et al.* 2006). Hence, there is a stringent need for

[1] a.a.elmualim@reading.ac.uk

collaboration between various organizations from architectural practices, consulting engineers, general contactors, specialized sub-contractors, manufacturers and material suppliers as well as management firms in the delivery of construction projects. This intra-organizational collaboration is mirrored by an inter-organizational practice. Furthermore, it is argued that individual and organizational behaviour is highly influenced by national culture (Hofstede 2001, 2003). The conflict arises when each organization or an individual within an organization aspires to meet their own interest ignoring the interest of others. The dichotomy is that many firms and individuals while engaging in collaborative practices seek opportunities to advance their interest through competitive practices. Such practices of collaboration and competition at both levels of intra or inter-organizations have caused the emergence of a culture of adversarial attitudes (Egan 1998), which is pertinent within construction and is decried by all (Green and May 2003). The most compelling and pressing question is why organizations and individuals develop such paradoxical practices of competition and collaboration? This paper attempts to address this paramount question by adopting a psycho-social approach that seeks to understand such dichotomy and advance a paradigm that is most befitting to healthy and genuine collaborative relationships in construction.

UNDERSTANDING CONSTRUCTION

Fragmentation of the UK construction industry

According to the figures from the Department of Trade and Industry (DTI), the UK construction employs more than 1.6 m people with a third registered as self-employed (DTI 2003). The UK construction industry is dominated by small and medium enterprises with annual output of more than £83.5bn. The sector is highly fragmented with low levels of workload continuity, little interdependence and communication and lack of trust. According to Egan (1998), this sector's fragmentation led to the extensive use of subcontracting and prevented the continuity of efficient and effective teamwork. However, this fragmentation assisted organizations in having greater flexibility to deal with highly varied workloads. Eventually the sector's overriding practice is characterized by adversarial relationship, low cost, short-term profits and opportunistic behaviour. Best practice initiatives introduced teamworking, collaborative working and the call for a higher level of trust are failing to bring about dramatic changes that are sought (Green and May 2003).

Despite the domination of small and medium enterprises for construction, the majority of work is carried out by large firms. These large construction firms are typically seen as hollowed-out organizations in that very few of them actually carry out the work themselves. Virtually all their work is carried out by subcontractors or by subcontracted labour. The large firms are thus more involved in managing the processes on projects rather than doing the work themselves. This has implications in that if collaborative relationships are to be formed to promote the interests at all levels closer to the workface and users, then this will probably have to take place with people from different organizations. Secondly, it means that large firms have limited influence on promoting effective communication at the levels that the work actually gets done. However, they have a great deal of influence in promoting learning among 'white collar' workers. A significant factor explaining the negative examples of intra or inter-organization collaboration is the relatively low level of trust that exists between organizations and individuals within these organizations. The importance of trust in facilitating knowledge sharing is increasingly being recognized, with a lack of trust likely to inhibit the extent to which people are willing to collaborate with each other (Hislop 2005).

Having said that, most large construction firms are project based organizations in that the firm together with all its employees are not all situated in one location but are ‘dispersed’ and are thus viewed as a conglomeration of various project based teams. The large contracting firm is therefore essentially an aggregation of the projects with which it is involved with at any point in time. Coupled with this, construction projects run to very tight timescales; thus, coming together to meet, for the purpose of sharing knowledge, is not seen as a priority for a number of project staff. Getting staff to collaborate online also poses its own difficulties in that on a number of projects the IT infrastructure which houses collaboration software, is not always available (Egbu 2004). Such reasoning is seen as the driver for the industrial recipe of construction.

The industrial recipe of construction has been defined as the overriding culture that typifies a particular industry. The industry recipe is thought to be particularly strong in the construction industry, the flavour of which is captured in the perceived view of the traditional design-tender-build method of procurement, in which design is separated from construction and the system is characterized by fragmentation, friction and mistrust. Newer forms of procurement, such as construction management and partnering, are being used, although slowly, as vehicles to change the industrial recipe. The aspect of mistrust that stems from the industrial recipe has particular relevance to the application of collaborative frameworks between and within organizations. Collaborative relationships are deemed to develop at their best in environments where trust is prevalent.

Dichotomy of competition and collaboration in construction

Much of the current discourse of competitiveness is derived from Michael Porter’s typology of competitive advantage (Porter 1980; Porter 1985, 1990). While Porter’s work initially focused on guiding firms whether or not to enter a particular industry, it has since become more commonly used to analyse relative market power as a means of informing strategic action. The analysis is often know as ‘Five Forces’, referring to the factors used. Porter proposes three generic strategies: cost leadership, differentiation and focus. Cost leadership strategies are deeply embedded within construction, largely because firms frequently struggle to differentiate their products. More recently, there is evidence of some companies adopting a ‘focus’ strategy by concentrating on particular market niches with a view to providing excellent services to a limited clientele. However, the assumption that such strategies are mutually exclusive has been repeatedly challenged in the literature. Furthermore, Porter notably offers little advice on how organizational resources are to be aligned in the effective implementation of the adopted strategy (Connor 2003; Flint 2000; Klein 2002).

Within the strategic management literature, the term competitive advantage remains ambiguous and is frequently criticized for being divorced from context. Competitive advantage is seemingly a relative term that defies universal definition. Whilst the discourse of competitive advantage remains attractive, there is little agreement on what it means in operational terms (Connor 2003; Klein 2002). The broader community of strategic management researchers are highly critical of Porter’s perceived lack of precision (Connor 2003; Flint 2000; Klein 2002).

The continued ambiguity of the discourse of competitive advantage has profound implications on the adopted managerial practices (Thomas 2003), particularly, in the UK construction industry. The narrative of competitiveness discourse mobilized depends in part on the vested interests of different institutionalized groups. Managerial practice in construction can be categorized into identifiable constituencies (assembly of people, materials and practices that are governed by power, social relations/interactions, material practices, institutions and rituals, beliefs and values and discourse) (Thomas 2003) and sub-constituencies of interests as ascribed by industry participants. These competitiveness constituencies can be broadly identified as: (i) construction academics; (ii) construction consultants; (iii) the policy makers; (iv) construction practicing managers; and (v) clients. Given the heterogeneity of the construction sector, the last two categories are likely to be broken down into several sub-constituencies (Elmualim *et al.* 2006).

Within the domain of public procurement, emphasis has switched away from competition towards partnership. Current notions of 'partnering' and 'collaborative working' are indicative of this same shift in discourse (Egan 1998; Latham 1994). The supposed dichotomy between competition and collaboration/partnership however continues to attract much debate within both the public and private sectors (DTI 1998; Egan 1998; Karlberg 2004). The distinction between competition and collaboration is something of a red herring. Firms seek to engage in collaboration as a means of securing competitive advantage, i.e. they seek collaboration as a means of securing long-term returns. Clients are likewise attracted to collaborative relationships on the basis of the alleged benefits of innovation and continuous improvement. Paradoxically, effective collaboration can therefore make construction firms and clients more competitive. Similar arguments apply throughout the supply chain, although there is frequently a significant inertia to be overcome before firms can switch to relational contracting. It must also be recognized that firms frequently have to operate collaboratively and competitively at the same time, thereby eroding any prospects of an associated 'culture change'. A further complication is introduced by the fact that some firms espouse the rhetoric of collaborative working whilst continuing to behave opportunistically.

MUTUALISTIC AND ADVERSARIAL RELATIONSHIPS

In today's western liberal culture, competitiveness and conflictual relationships are ubiquitous cultural practices that are hegemonic in nature serving the interests of few. Such competitive and coflictual relationships are becoming the norm. In conventional wisdom, such relationships are inevitable expression of human nature (Karlberg 2004). According to Karlberg (2004), "throughout the contemporary public sphere, competitive and conflictual practices have become institutionalized norms. Indeed, contest models of social organizations and protest models of social change have become so ubiquitous that they tend to appear normal, natural and inevitable to those raised in western-liberal cultures." It is further argued that the norm makes it difficult to envisage alternatives (Karlberg 2004). To advance collaboration through mutualistic relationships require understanding of power sharing and distribution amongst individuals, across organizations and society at large. Indeed "in the long history of mankind those who learned to collaborate and improvise most effectively have prevailed" (Darwin 1859). Our existence as human beings will depend greatly on mankind to act together, though we might be thinking differently (Hofstede 2001). Archaeological and anthropological research suggests evidences of both modes of behaviour as two strands woven in the human culture. The paramount questions are; is the culture of contest and protest a reflection of human nature? do humans have the potential for either adversarial or mutualistic behaviours? What are the implications? Which culture promotes social justice and ecological sustainability?

Adversarialism

Adeversarialism is the pursuit of mutually exclusive interests by individuals or groups working against one another. Adversarialism appears in the form of contest, competition and confrontational relationships. According to Karlberg (2004) "though not all of adversary practices and forms of expressions may not be problematic, these forms of cultural codes are maladaptive, maladjusted and maladroit". Adversarialism creates a division between winners and losers.

Mutualism

On the other hand mutualism is the pursuit of mutually inclusive gains by individuals or groups working with one another. Mutualism enhances the chances of all members of the group to have the benefit of being winners, though the sense of winning might not be of a tangible form. Many schools of thoughts such as feminism, systems theory, ecology and environmentalism, communication theory, and alternative dispute resolutions advocate the vitality of mutualistic relationships to advance human progress. However, mutualisim is difficult to evaluate and to a greater extent is being marginalized because of the norms and therefore appear naive and idealistic (Karlberg 2004). To fully appreciate the benefit of the application of mutualistic relationship in real cultural communities, there will be a stringent need to have all embracing vision established through the understanding of structures, practices, institutional structures and strategies and collective decision making processes.

Tripartite axiological system

Construction organizations are shaped by divergent objectives and specific interests of different individuals, groups or departments. Each one with their own power base and discourse to legitimize their interest to the wider organization (Hardy *et al.* 2000). This specifically identifies the fragmentation of the construction industry as a whole and organizations operating in the construction market. Hence, the construction organizations can be described as pluralistic organizations that are characterized by multiple objectives, diffuse power and knowledge based work processes (Denis *et al.* 2007). According to Denis *et al*. (2007), pluralistic organizations throw three types of problems at those who want to promote concerted organizational actions; Individual autonomy that is associated with a diffusion of power and emphasis on knowledge-based work. Pluralistic organizations endeavour to provide a broad scope for individual action, encouraging local development and flexibility. This can become a barrier to the integration and coordination of the organization as individuals have the freedom to dissociate from the common objectives of the organizations. The second problem is the "inflationary consensus". Under a diffused power system, in practice, building a consensual decision may be achieved at the expense of realism. The third is that decisions and strategies are produced by the same people and processes which can result in producing a various layering of structures (Denis *et al.* 2007).

In any construction project individuals are required to make decisions in relation to other parties in the project. These decisions might be enacted in a mutualistic or adversarial manner to promote the interest of the whole entity or all one's self or organization limited interest. Those individuals are part of the organization and part of the society as a whole. Figure 1 shows this tripartite axiological system showing the interaction between society, firms and individuals.

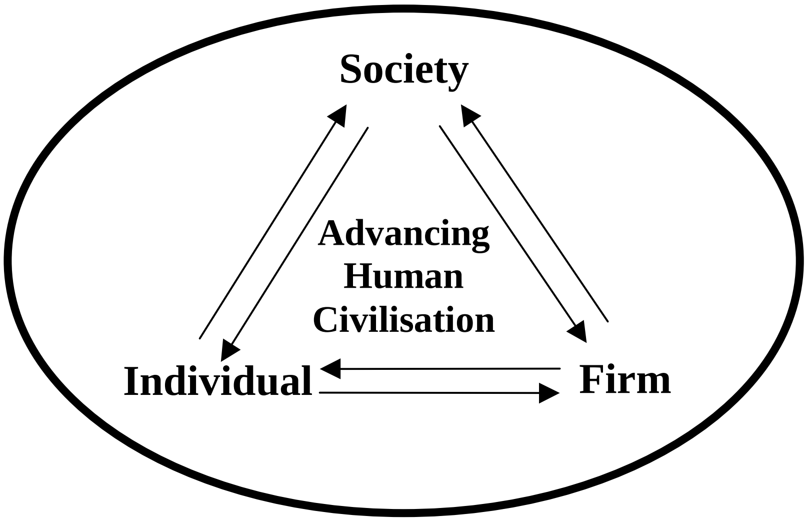


Figure 1: The tripartite axiological influences

This system is inherently an "Irreducibly complex system" (Karlberg 2004). It is evident that there is interplay between psychological and sociological behavioural dynamics (Lips-Wiersma 2002). “Psychological theory is fundamentally concerned with constellations of personal beliefs, attitudes and attributes and based on the assumption that individuals potentially have a moderate degree of destiny or control in their career” (Lips-Wiersma 2002). While sociological theories emphasizes the role of the environment based on the assumption that reality is socially constructed and institutionally influenced, such as culture and structure, play an important role in shaping personal behaviour, experiences and opportunities. Individual shared stories showed the duality of psychological and sociological influences and highlighted a wide range of relationships and interactions. There is an assumption that in changing oneself one can exert influence on their organization and hence the proposition of one can change the world. Likewise, individual choices, decisions and behaviours are greatly influenced by organizational structure and culture (Lips-Wiersma 2002).

In attempting to fully understand the drivers of mutualistic or adversarial behaviours, a different but complementary perspective is needed. This perspective is the notion of this paper. It is argued that to understand the model of adversarial behaviours in construction and advance mutualistic relationship, a perspective of psycho- structural and socio-structural is needed. This perspective further can be enlightened by understanding power and it is distribution. Such a joint perspective helps shed lights on the reasoning underpinning adversarial behaviours.

PSYCHO AND SOCIO-STRUCTURAL PERSPECTIVE

Culture has a complex and different meaning and shades (Hofstede 2001, 2003). It is a collection of systems of representations, meanings, beliefs, and other ideological variations among a particular social groups (Hofstede 2001). It encompasses political, economic, legal and other structural variations among social groups (Karlberg 2004). Culture can be seen as social heritage, a phenomena that is socially learned or constructed, relatively fluid and variable between populations and across generations, and hence there is a infinite cultural representations (Hofstede 2001). At an organizational level culture is the collection of relatively uniform and enduring values, beliefs and customs, traditions and practices that are shared by an organization's members, learned by new recruits and transmitted from one generation of employees to the next; it is the way we do things around here; the wary we interact; and the way we cooperate or compete. Hofstede (2001) refers to the mental programming of humans that is physically is determined by the brain cells. However, as it is difficult to observe these mental programmes physically but are observed through humans behaviour (Hofstede 2001). According to Hofstede (2001), every person's mental programming is partly unique, partly shared with others at the three levels of individual, collective and universal.

In the broadest sense culture is the entire social heritage of a community including material, ideological and structural expressions. These contingent expressions can be socially learned or constructed. For example our need to eat or drink are innate characteristics of our human nature, however, all forms of our tastes in food to the diverse ways of producing and distributing food are expression of our human culture. Indeed, and according to anthropologist Clifford Geertz "our capacity to speak is surely innate; our capacity to speak English is surely cultural" (Geertz 1973). The interplay between human nature and culture is well established as our need for culture itself is an innate characteristics of human nature. Hence the distinction between nature and culture is very subtle and very complex.

Having said that, the distinction between natural and cultural practices is of paramount importance in the study of managerial practices in construction. As adversarial practices in construction have been internalized, they are then represented as natural and inevitable to those who have internalized them. The prevailing assumptions are that adversarial practices are, as commonly argued, part of the fundamental make up of human nature as we are intrinsically selfish and aggressive (Hofstede 2003). However, Karlberg (2004) suggested such assumptions are not only misinformed but socially oppressive and ecologically unsustainable and that there is a need in establishing norms to regulate human nature (culture).

Cultures are not monolithic entities and that processes of physical and cultural evolutions are not distinct and nor sequential. The fundamental issue is that cultural practices can be internalized and therefore appear natural, inevitable and impossible to change. In his study, Hofstede (2001) found variations of individual behaviour across the globe. These behavioural variations where an individual can be cooperative or competitive depends on power distance (relating to human equality), uncertainty avoidance (related to stress level in unknown circumstances), individualism versus collectivism (related to the individual integration into the primary group), masculinity versus femininity (related to the division of the emotional roles of men and women in society) and long-term versus short term that relate to the focus of people's efforts to the present or the future.

It is evident that to understand human behaviour one needs to appreciate the two levels of culture the socio-structural and the psycho-structural elements (Hofstede 2001, 2003). Socio-structural element of culture (the culturally contingent models of social organizations) deals with groups and organizations of society, relationships between labour and capital in a capitalist economy and between first and third world nations in a post-colonial world order. Changes are made by reforming underlying structures- making of laws and regulations (Karlberg 2004).

Psycho-structural dimensions of culture (understanding the contingent structure of the human mind) highlight subjective understandings of individuals. Changes here are by raising awareness, rethinking values or identities or reforming attitudes and beliefs (the subjective structure of the mind rather than the structure of social organizations). This can be appreciated in the early years of development of individuals mostly in childhood and youth. Although media campaigns for different age groups or specific groups can be used these days to achieve the desired changes (Karlberg 2004).

It appears that there is a need for a dual strategy. Individually humans have the potential for adversarial as well as mutualistic behaviour. The degree to which we realize either of these potentials is a function of the cultures we are raised within (Hofstede 2001; Karlberg 2004).

UNDERSTANDING POWER TO ADVANCE MUTUALISM

Hislop (2005) argues that one of the major criticisms of the majority of the mainstream management literature is the neglect of issues of power and conflict. Fundamentally, individuals and organizations in construction have inherent tensions built into them which unavoidably results in them possessing an, 'unequal distribution of power'. The uneven distribution of power results from the reality of the diversity of construction and hence participants in the processes are not necessarily equal. This uneven distribution of power creates potential conflicts in the processes of construction projects (Wild 2002). According Karlberg (2004), there are four distinct power distribution whether related to individuals or organizations. The first model of power distribution is power over or to have power driven mainly by culture of contest. This model of power distribution results in a state of inequality between parties coupled with adversarial relationships (see Figure 2). The second model of power distribution is assisted power which results again in a state of equality but might help to develop mutual relationships. The third model is a balance of power that results in equality between parties with probability of the parties resorting to adversarial attitudes. The fourth model is mutual empowerment or power with (mutualism). This model clearly advances mutualistic relationships on an equal basis.

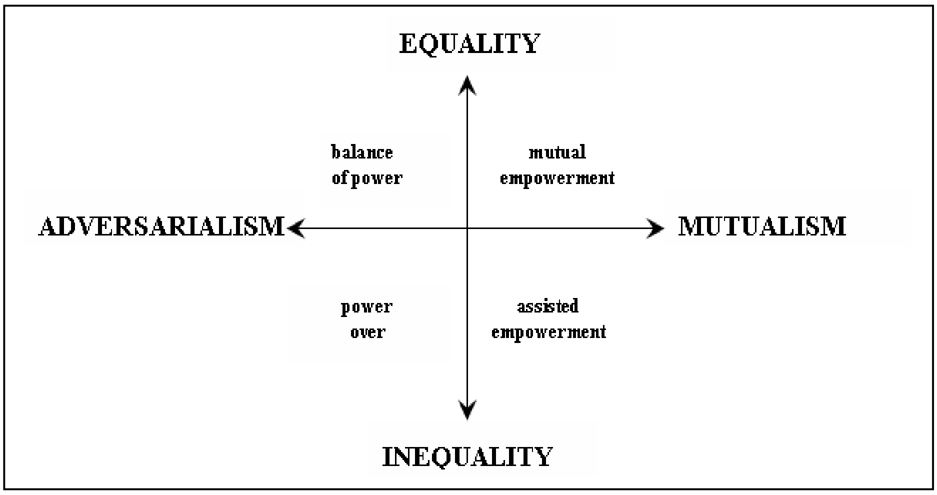


Figure 2: Power distribution and relationships (Karlberg 2004)

Indeed, the model of contest can be seen in our economic, legal and political systems. In academia, the Greek-based competition epistemological model of contest of ideas (intellectual contests) is viewed as the best way to generate knowledge by structuring its production as a contest between competing ideas. This assumption views human as aggressive and greedy by nature – “natural selection” (Karlberg 2004). However, cultural models of cooperation are seen as enablers for human to survive rather than aggressive impulses. “Rejecting the fundamentally self-interested and competitive understanding “*homo economus*”, economist expand the understanding of human nature as cooperative, altruistic and even self-sacrificing” (Geertz 1973). Such assumptions can also be seen in game theories and economics. Furthermore other schools of thoughts such Feminism, System theory, Ecology/Environmentalist and communication theories advocate the later models of culture, a culture of mutualism.

Feminism argues that aggressive and competitive structures serve as a structure for male domination. In feminist theory, empowering others is seen as a rewarding and gratifying activity. Women stress power as a capacity rather than domination (Karlberg 2004). This paradigm of thinking is complemented by System theory. System theory is a relational paradigm that characterizes the study of complex systems adapting a holistic or systemic focus that reveals the connections or interrelations within the system. It aims to understand the wholeness or interdependence of a system where the system is adapting to an organic view of the world/system. It further emphasizes the reality of increasing interdependence and the need for a movement towards post-hegemonic cultures (Karlberg 2004). System thinking requires that individual members of a system should be attached to the vital interest of the whole and not to hesitate to subordinate every particular interest for the sake of over-riding interests of the whole. In a world of increasing interdependency, the interests of the part are best reached by the advantage of the whole. As no lasting results can be achieved by any of the component parts if the general interests of the whole entity itself are neglected or marginalized by any of the parts. System thinking advocates an integrative power model. This integrative power model is seen as “the capacity to build organizations, to create families and groups, to inspire loyalty, to bind people together, to develop legitimacy” (Karlberg 2004). Such are the underpinning of the ecology/environmentalism models that provide an epistemological model for reconciling “oppositional” viewpoints, where the differing views are seen as complementary and necessary for the dynamic of the group (Karlberg 2004).

Another school of thought that promotes mutualistic relationships is communication theories. Theories of interpersonal communication suggest that adversarial modes are counterproductive within families, among friends and among co-workers. Individuals cannot afford to offend each other especially in long term relationships. Communication theory advances the interest of the group by developing a collective discourse through dialogue. Dialogue opens up the channels that “contribute to the thinking about an issue so that everyone involved gains a greater understanding of the issue in its subtlety, richness and complexity … an understanding that engenders appreciation, value and sense of equality. … Absent are efforts to dominate others because the goal is the understanding and appreciation another’s perspective rather than the denigration of it simply because it is different”(Foss and Griffin 1995).

In adopting such psycho and social perspective, as part of the discourse in construction, one can influence the thinking as through thinking, actions can be generated for genuine collaboration. This in turn will create a paradigm shift for collaboration to advance mutualaistic relationships in construction.

CONCLUSIONS

The construction industry is widely viewed as a fragmented and diverse industry. As it is a project-based industry, the delivery of construction projects requires the participation of various agents. Each agent comes with their own cultural values, modes of operation and interests. Such cultural values and interests produce a power distribution system amongst participants that leads to conflict and adversarial relationships. Adversarial relationships are strongly disapproved by all, particularly policy-makers. However, organizations within construction while espousing the collaboration rhetoric of the policy-makers, they exploit every opportunity to gain a competitive advantage over their rivals and other organizations in the supply chain.

This paper attempts to re-address the issues of collaboration and competitiveness in construction via different yet complementary approaches of psycho and socio structural study. This complementary approach seeks to discern the dichotomy of collaboration and competitiveness by understanding power distribution among social groups. Such an approach sheds light on the nature of power, its distribution and its influence on driving competitive or genuine collaborative behaviours as foreseen by individual, organization and society as whole. It is argued that our culture of competition has become the norm and that the norm makes it difficult for individuals and organizations to see other alternatives. Contests are being seen as normal and necessary models of social interactions and, hence, "normative adversarialism" has become the predominant strand in contemporary western-liberal societies. Psycho and socio structural approaches show that individuals are greatly influenced by their organizations. Both individual and organizations are influenced by the wider society in a very complex and intertwined tripartite axiological system. Individual humans are intrinsically and culturally programmed towards competitive and collaborative behaviours. It is argued that in the post-hegemonic society cooperation and mutualistic relationships will be best to serve the interests of the participants of construction projects delivery. Such a view is supported by various schools of thoughts such as communication theory, system thinking, feminism, and environmentalists groups. Competitiveness discourse is better seen as a mean for training or acquiring cooperative skills in order to advancing collaboration and mutualistic relationships in construction.

ACKNOWLEDGEMENT

The work presented here is part of the Big Ideas project. An EPSRC-funded collaborative research project between Loughborough University, the University of Reading and the University of Salford IMRCs. Acknowledgment is extended to all colleagues across the three institutions.

REFERENCES

Connor, T (2003) Managing for Competitiveness: a proposed model for managerial focus. *Strategic Change*, **12**(4), 195–207.

Darwin, C (1859) The origin of the species.

Denis, J-L, Langley, A and Rouleau, L (2007) Strategizing in pluralistic contexts: Rethinking theoretical frames. *Human Relations*, **60**(1), 179–215.

Department of Trade and Industry (DTI) (1998) *Competitive Futures: Building the Knowledge Driven Economy*. London: Department of Trade and Industry.

Egan, J (1998) *Rethinking Construction*. London: DETR/Stationery Office.

Egbu, C O (2004) Managing Knowledge and Intellectual Capital for Improved Organizational Innovations in the Construction Industry: An Examination of Critical Success Factors. *Engineering, Construction and Architectural Management*, **11**(5), 301–15.

Elmualim, A A, Green, S D, Larsen, G and Kao, C C (2006) The discourse of construction competitiveness: Material consequences and localised resistance. *In*: *Joint International Conference on Construction Culture, Innovation and Management (CCIM)*, 26–9 November 2006, Dubai. The British University in Dubai, UAE and CIB.

Flint, G D (2000) What is the Meaning of Competitive Advantage? *Advances in Competitiveness Research*, **8**(1), 121–9.

Foss, S and Griffin, C (1995) Beyond persuasion: A proposal for an invitational rhetoric. *Communication Monographs*, **62**(March), 2–18.

Geertz, C (1973) *The interpretation of cultures: Selected essays*. New York: Fontana.

Green, S D and May, S C (2003) Re-engineering Construction: going against the grain. *Building Research & Information*, **31**(2), 97–106.

Hardy, C, Palmer, I and Phillips, N (2000) Discourse as a strategic resource. *Human Relations*, **53**(9), 1227–48.

Hislop, D (2005) *Knowledge Management in Organisations*. New York: Oxford University Press.

Hofstede, G (2001) *Culture's consequences: comparing values, behaviours, institutions, and organisations across nations*. London: Sage Publications.

Hofstede, G (2003) *Cultures and organizations: Intercultural cooperation and its importance for survival-Software of the mind*. London: Profile Books Ltd.

Karlberg, M (2004) *Beyond the Culture of Contest*. Oxford: George Roland Publisher.

Klein, J (2002) Beyond Competitive Advantage. *Strategic Change*, **11**(6), 317–27.

Latham, M (1994) *Constructing the Team*, London: HMSO.

Lips-Wiersma, M (2002) Analysing the career concerns of spiritually oriented people: lessons for contemporary organizations. *Career Development International*, **7**(7), 285–397.

Porter, M E (1980) *Competitive Strategy* **-** *Techniques for Analysing Industries and Competitors*. Free Press.

Porter, M E (1985) *Competitive Advantage*. New York: Free Press.

Porter, M E (1990) *The competitive advantage of nations*. London: Macmillan.

Thomas, P (2003) The Recontextualisation of Management: A Discourse-based Approach to Analysing the Development of Management Thinking. *Journal of Management Studies*, **40**(4), 775–801.

Wild, A (2002) The unmanageability of construction and the theoretical psycho-social dynamics of projects. *Engineering, Construction and Architectural Management*, **9**(4), 345–51.

THE ‘PRACTICE TURN’ IN ORGANIZATIONAL STUDIES AND CONSTRUCTION MANAGEMENT RESEARCH

Mike Bresnen[1]

University of Leicester School of Management, University Road, Leicester, LE1 7RH, UK

The ‘practice turn’ in organizational studies has recently emerged as an important set of perspectives which has implications for understanding processes of knowing and learning within and between organizations. Consisting of a range of different approaches, it emphasizes the situated nature of knowing and learning in practice and offers an alternative to understanding human action that transcends the dualism of structure and agency effects on action. The ontological and epistemological underpinnings of a practice-based approach are assessed before attention is directed towards the implications for construction management theory and research and for an understanding of knowledge, learning and change in project-based organization.

Keywords: organizational behaviour, organizational analysis, organizational learning, practice-based perspectives.

INTRODUCTION

Within mainstream organizational and management studies, there has been considerable interest in recent years in ‘practice-based’ views of organization – particularly in the area of organizational knowledge and learning. In contrast to approaches that take a more abstracted or ‘commodified’ view of knowledge management, innovation, organizational change and learning (and which treat, for example, ‘knowledge’ as an object that can be shared, transferred and manipulated), practice-based theorists and researchers have focused attention instead upon what people actually do (thus, treating processes of ‘knowing’ as of central importance and interest) (e.g. Orlikowski 2002). Rather than beginning with theories abstracted from action, therefore, theory and research from a practice-based perspective takes a more inductive line, in which interest is directed towards the ways in which practices (and, through them, structures and systems) are constituted and re-constituted through the complex and situated use of a wide array of tools, technologies, objects, languages and bodies of knowledge that populate a domain of activity.

Although the ‘practice turn’ in organizational studies stems from a range of theoretical traditions (including structuration theory, activity theory, actor-network theory and ethnomethodology), there are common concerns and interests – for example, in exploring the constitution of action through localized practices; and in understanding how interaction is affected by the role of technologies and objects (Carlile 2004). Underpinning research in this area has also been a long-standing critical interest in the importance of power for understanding how practices are constituted and how they, in

[1] m.bresnen@le.ac.uk

turn, relate to broader social structures in which action is embedded (e.g. Foucault 1980; Giddens 1990).

Drawing indirectly upon research undertaken recently by the author into organizational knowledge and learning processes in project-based organizational forms (Bresnen *et al.* 2003, 2005a), this paper explores the applications of practice-based theorizing and research to the further development of construction management research, assessing in particular, the usefulness of such approaches for uncovering processes relating to, inter alia: the diffusion of innovation and 'best practice'; the effecting of organizational change within the industry; the effects of physical and other objects in mediating inter-organizational working relationships; and the effects of different 'professional' working practices on project team integration.

Although the paper takes a more theoretical than empirical line, it also takes the position that an emphasis on understanding practice and its relationship with theory is critically important in an age in which 'Mode 2' forms of knowledge production are considered vitally important (Gibbons *et al.* 1994), and where, in organizational and management studies at least, there is a perceived need to overcome the 'double hurdle' of academic rigour and practical relevance (Pettigrew 2001) and be involved in 'engaged scholarship' (Van de Ven and Johnson 2006). At the same time, there are important methodological implications for construction management research that emerge from an engagement with practice-based perspectives, not least of which is the importance it places on ethnography and more in-depth methods, such as observation.

THE PRACTICE TURN IN ORGANIZATIONAL STUDIES

Practice-based perspectives in organizational studies have emerged in recent years partly as a response to the long-standing problem in philosophy and social theory of the dualism that exists in the relationship between agency and structure as the basis of human action (e.g. Giddens 1990). Put simply, the problem of understanding action is whether one attaches primacy to the influence of individual freewill or to social structure as the basis of human behaviour. Differentiation in the social sciences between, in particular, psychology and sociology reflects this difference in emphasis between, on the one hand, individual cognition and agency and, on the other hand, social structure as the basis for action. Although these disciplines do attempt to meet in the middle (via the sub-discipline of social psychology), the recursive nature of the relationship between agency and structure is never fully resolved. So, for example, if social structures shape, if not determine, our behaviour, what part does agency play (or what part *can* it play) in the production of social order, the enactment of social systems and the development of social change?

Practice-based approaches are an attempt to transcend this dualism and overcome the schism between psychological and social approaches that lies at the heart of the social sciences by proposing the 'field of practice' as the appropriate point of departure for the study of human behaviour. Rooted in various philosophical traditions – including phenomenology, pragmatism and Wittgenstein's philosophy – the approach sees the social world as "a field of embodied, materially interwoven practices centrally organized around shared practical understandings" (Schatzki *et al.* 2001: 3).

A practice-based perspective therefore contrasts, on the one hand, with structuralist perspectives that emphasize the (determining) influence of social structure on action and the establishment of custom-like regularities (e.g. routines). Instead, practices are actively constituted and are more fluid and unfolding than more regularized routines (Schatzki *et al.* 2001: 6-7, 13). On the other hand, although there is more connection with individual action, practice-based approaches also contrast with more individualist perspectives (e.g. symbolic interactionism) by emphasizing the *embodiment* of cognitive capacities, not just the importance of cognitive abilities linked to reasoning and freewill. So, for example, practices, which can be minimally defined as ‘arrays of human activity’ are seen as “embodied, materially mediated arrays of human activity centrally organized around shared understandings” (Schatzki *et al.* 2001: 2). The emphasis is on embodied cognitive capacities and the importance of tacit shared understanding centred upon particular fields of practice. In turn, human agents and their identity are bound to practices (Schatzki *et al.* 2001: 11).

Given the scope offered by such a definition, it is perhaps not surprising to find that there is no single unifying practice-based theory or approach. Indeed, the range of perspectives encompassed is tremendously wide, including approaches such as phenomenology, hermeneutics and ethnomethodology, as well as the more specific theoretical frameworks of activity theory (Blackler 1993), actor-network theory (Callon 1985; Latour 1986; Law 1992) and Bordieu’s (1977, 1990) concept of the ‘habitus’. Despite this variation, however, there are important points of convergence, particularly in the emphasis placed upon understanding knowing and learning as unfolding processes centred upon practice (e.g. Orlikowski 2002). According to Nicolini *et al.* (2003: 3), organizational knowing is “situated in the system of ongoing practices of action in ways that are relational, mediated by artefacts, and always rooted in a context of interaction. Such knowledge is thus acquired through some form of participation, and is continually reproduced and negotiated; that is, it is always dynamic and provisional”. Crucially, therefore, practice-based approaches emphasize the fluidity of knowledge and learning and the difficulties of codifying knowledge and, thus, of representing knowledge of such practice (Shatzki *et al.* 2001: 8-9).

Inevitably, however, there are also important differences between practice-based perspectives, most notably perhaps in the emphasis placed upon the role of material objects. According to Schatzki *et al.* (2001: 11), practices are “materially mediated” nexuses of activity and, as such, objects play an important part in practice and in understanding processes of knowing and learning. Work on ‘boundary objects’, for example (Boland and Tenkasi 1995), demonstrates their importance in mediating communication within a joint field of practice and in providing the “tangible definitions” needed to allow knowledge to be shared or transformed (Bechky 2003; Carlile 2004). Work within an actor-network theory perspective, however, goes much further than this in proposing that objects themselves can play a part in propagating practices – effectively having agency and some impact upon behaviour through their role as ‘actants’ (Law 1992). Such a proposition has, of course, been subject to considerable criticism and debate. Nevertheless, it is clear that there exist important differences between practice-based approaches in the emphasis they place upon the role and impact of objects – both material and symbolic (Nicolini *et al.* 2003: 22).

There are also important differences in the emphasis placed upon issues of power and control within a practice-based perspective (Nicolini *et al.* 2003: 24). Although issues of power do tend to get acknowledged more in practice-based approaches, in those more concerned with integration within and across complex fields of practice (e.g. Brown and Duguid 2001; Carlile 2004; Wenger 1998), questions of control, hegemony and domination in social relations between actors tend to get downplayed.

In contrast, other perspectives that derive more from a poststructuralist perspective see relations of power as of central importance in constituting fields of practice through their impact on what constitutes knowledge, meaning, practice and identity. So, for example, systems of power within which social interaction is embedded have an important influence on practice through the mutual constitution of power and knowledge which, in turn, shapes meaning and identity through normalized conceptions of what constitutes practice (Foucault 1980).

Practice-based approaches have therefore become central to understanding organizational knowing, learning and change. In particular, work that draws upon concepts such as that of the 'community of practice' (Lave and Wenger 1991) has to some extent superseded more established IT-based approaches to 'knowledge management', in recognition of the highly situated nature of knowledge and learning and of the importance of social interaction through joint practice as the medium through which processes such as knowledge sharing, knowledge integration, knowledge creation and organizational learning take place (Brown and Duguid 2001). More generally, an understanding of the processes of knowing and learning as they occur through social interaction situated in practice and mediated through language and a variety of forms of material and symbolic objects has become an important part of understanding issues associated with organizational 'becoming', enactment and change (Orlikowski 2002; Tsoukas and Chia 2002).

THEORY AND PRACTICE IN 'MODE 2' RESEARCH

A focus on practice too dovetails with clarion calls from within the field of organization studies for research to relate more directly to the context of application, and to reflect more the needs of the range of stakeholders involved. Often referred to as a 'Mode 2' form of knowledge production (Gibbons *et al.* 1994), this represents a shift away from a form of knowledge creation that emphasizes the definition of problems by members of the academic community and the production of knowledge in stable, homogenous, university-based, disciplinary groups ('Mode 1'); towards a system in which knowledge is produced in the context of application by diverse, trans-disciplinary groups in decentred and dispersed networks of organizations.

Such a shift in emphasis has been criticized on the grounds of merely replacing one set of knowledge production values with another, equally politicized set of values (Grey 2001). Nevertheless, it does represent an important shift in thinking about the basis of knowledge about organization, the range of stakeholder interests and influences involved and, crucially important, the link between knowledge generation and the application of knowledge to practice (Starkey and Madan 2001). It also links in with wider debates within the field about the importance, particularly within the field of organizational/management studies, of overcoming the inevitable 'double hurdle' in research of academic rigour and practical relevance (Pettigrew 2001) and, more generally, with the renewed emphasis within the academy on 'engaged scholarship' (Van de Ven and Johnson 2006).

At other levels, however, the practice turn in organization studies points to a very different set of implications with regard to issues of research approach and method. At an ontological level, the suggested more relational, constructive, heterogeneous and situated nature of knowing and learning, combined with a more indeterminate view of supposedly fixed elements such as structure, knowledge and boundary not only sits very uneasily with the very idea of institutionalized patterns of 'knowledge production', but also brings into question any firm assumptions we may make about the aims of knowledge production and the range of stakeholders interests involved. As Nicolini *et al.* (2003: 27) put it: "From a practice perspective, the world appears to be relationally constituted, a seamless web of heterogeneous elements kept together and perpetuated by active processes of ordering and sense-making. Practices – including discursive practices – are a bricolage of material, mental, social and cultural resources". Whether or not one takes an approach that emphasizes relations of power and control, it is clear from this that knowing and learning are highly situated in practice, as well as continually constructed, re-constructed and contested.

A similar set of issues arises when one considers the epistemological implications of a practice-based approach to knowledge and learning. The strength of a practice-based approach is in getting close to practice and in exploring action in 'real time' – attempting to ground theory better in what it is that people actually do, rather than beginning with theories that are abstracted from practice. At one level, this would seem to dovetail well with the aim of grounding knowledge in experience and in effecting changes in practice where needed. An emphasis on situated learning and greater sensitivity to what is local and contingent would therefore appear to introduce a degree of social realism into the research process (via grounded theorizing) and a corresponding emphasis on action-centred and experiential learning.

At the same time, however, the methods implied by a practice-based perspective tend to rely more upon anthropological-ethnographic and sociological-participant observer techniques for conducting research. While such methods are by no means inconsistent with the level of engagement necessary for conducting action-based research, they do however proceed from very different assumptions from those methods more commonly used in applied business and management research (Bryman and Bell 2007). Not only do they take a much more qualitative, open-ended line for the study of organizational phenomena, they also tend to eschew any kind of privileged perspective on the issue at hand, in preference to taking as paramount the subjective position of those researched. In other words, such methods are not particularly well suited to, or even consistent with, an agenda for research that is determined 'top down' from a purely managerial perspective (even if that agenda is explicitly concerned with understanding subjective perceptions or attitudes).

Taken together, these characteristics of a practice-based perspective on knowing and learning in organizations suggest there are two main implications for management research – including that relating to the construction industry context. The first is that research aimed at understanding organizational processes from a practice-based perspective need to adopt methods that are sensitive to and suited to the highly situated, socialized and fluid nature of knowing and learning in practice. The second is that such research is not necessarily of a type that easily reconciles the needs and orientations of researcher and practitioner.

IMPLICATIONS FOR CONSTRUCTION MANAGEMENT

The above discussion suggests, of course, a number of key challenges in attempts to apply practice-based thinking to the context of the construction sector. However, it also suggests a number of ways in which application of practice based perspectives to the construction industry context can make not only a significant contribution towards understanding organizational processes within the sector, but can also contribute to a greater understanding of practice-based perspectives more generally.

One important area in which a practice-based approach can throw some significant light upon organizational processes is in the diffusion of innovation and 'best practice' within the industry and in related areas concerned with knowledge sharing/diffusion and organizational change. The prospects for innovation within the industry and for applying 'best practices' to construction management – particularly those drawn from the manufacturing sector – form a constant theme in discourse within the industry (e.g. Gann 2000). Yet, this co-exists with repeated observations of the difficulties of developing innovation and diffusing and implementing 'best practice' within the sector – difficulties that stem, at least in part, from the project-based nature of working (Gann 2001; Winch 1998).

Research recently undertaken has begun to explore in more depth and from a practice-based perspective the organizational aspects of project-based working that inhibit the spread and implementation of new management ideas, focusing upon dispersed organizational working and the effect that this has upon attempts to embrace and embed new working practices. So, for example, it becomes apparent that there are limits to knowledge codification in project-based settings that create important constraints upon project-based learning (Bresnen *et al.* 2003); moreover, that decentralized project-based working and project-based organizational forms do not necessarily provide a wholly suitable backdrop for the emergence and knowledge-sharing benefits of 'communities of practice' as traditionally conceptualized (Bresnen 2006a; Lindkvist 2005). Further research undertaken recently by the author suggests that the dispersed management practices that characterize construction and other project work create additional challenges in attempts to embed new ways of working (Bresnen *et al.* 2005a). These relate to the distribution of power/knowledge within project-based organization and the lack of synchronicity between new management initiatives and existing project management practices (Bresnen *et al.* 2005b).

All of these findings suggest there is some value in taking a more situated view of learning within the context of construction and in applying ideas that take a more politically-sensitized approach to understanding relations of power within communities and networks of practice (Contu and Willmott 2003; Swan and Scarbrough 2005). They also suggest that there are key aspects of the construction industry context that have important determining or constraining effects on processes of knowledge, learning, innovation and change which also have resonance with similar conditions found elsewhere (and which thus suggest the wider generalizability of construction management research). These contextual characteristics include the project-based, decentralized, transient and inter-organizational nature of project-based working in construction and relevant comparative settings include sectors such as film-making (DeFillippi and Arthur 2001) and biotechnology (Powell *et al.* 1996).

Another area in which innovation is important, and in which a practice-based approach can through some light upon the factors enabling and inhibiting change, is in the development and application of information and communication technologies to support project design and management processes. As suggested above, recent work has illustrated the importance of understanding the crucially important and complex relationship between new technology applications and social practices – for example, in the realm of 'knowledge management' applications (Bresnen *et al*. 2003). Attention has also been directed towards understanding the socially constructed, flexible and contested nature of the technologies themselves and how the fundamental malleability of the technology that results not only shapes, but also is shaped by, joint working practices (e.g. Harty 2005). The role of visual practices and associated artefacts has also been the subject of recent interests in terms of their impact upon processes of design (Whyte *et al.* 2007), including consideration of their effects as inscription devices upon sense-making and the politics of design (Bendixen and Koch 2007).

Taken together, such research also points to the crucial importance of objects – both material and symbolic – in mediating the social interaction involved in complex project design and construction processes (Bresnen 2006b). At the same time, however, research also ironically emphasizes the limiting effects of decentralized project-based working upon the use of boundary objects to provide internal cohesion and integration (Sapsed and Salter 2004). Consequently, not only might such research throw some important light on the roles of objects in mediating inter- (and intra-) organizational working relationships in construction, it also has important implications for understanding the role of objects in more decentralized and inter-organizational fields of practice that are typically associated with various forms of project – including, but not restricted to, those found in construction.

A further area in which a practice-based approach can make a very useful contribution to understanding construction management (and broader project management) processes is in understanding the effects of different working practices amongst members of the organizationally and professionally diverse team commonly found working together on construction projects. Again, the problem of inter-disciplinary and cross-organizational working involved on construction projects has historically – and almost ritually – been held up as a major factor leading to problems of fragmentation, poor communication and integration within the sector. However, the response has commonly been to apply a mode of analysis that invokes a more orthodox and unitary perspective that treats the problem of cultural differentiation as one requiring structural mechanism and/or efforts at cultural alignment to create better integration within the team (Phua 2004).

A practice-based approach, on the other hand, enables a deeper, more ethnographic exploration of the social processes involved in the developments of working practices – both those that derive from particular ‘epistemic cultures’ (cf. Knorr-Cetina 1999) and community-based activity (e.g. Gherardi and Nicolini 2003), as well as those that relate to the variety of practical predispositions that actors bring to joint activity – as signified in the concept of the ‘habitus’ (Bordieu 1990). Indeed, similarities and differences in predispositions towards practice within the project team may reflect the cultural and social capital that different groups bring to the relationship which, in turn, has an important bearing upon interaction and integration within the team.

The range of practice-based perspectives is, as already mentioned, wide. However, a few further general and tentative suggestions can be made on the basis of the range of perspectives signalled up earlier. An activity theory approach, for example (Blackler *et al.* 2000), would view the undertaking of a building project as a complex activity system, involving joint endeavour and a complex division of labour, where activities are mediated by language and a range of technological artefacts. Importantly, activity theory also recognizes the differing logics of action involved and the fact that such systems are disturbance-producing – an observation that will not only resonate with those familiar with the conflicts and differences found amongst members of building teams, but which also allows for the transformation of practice over time.

The application of actor-network theory or the ‘sociology of translation’ has already been implicitly referred to as underpinning much of the work on technologies as flexible artefacts (e.g. Harty 2005). Suchman’s (2000) work in this area, for example, shows how, in the specific case of engineering projects, it is possible to depict the task of building a bridge as a complex job of aligning expertise, motivations and interests amongst a range of human actors and non-human elements in a highly fluid stream of sense-making activity that constitutes and re-constitutes relations amongst interested parties in a highly variable and contingent way. Further insights from an actor-network theory perspective might come from understanding the ‘obligatory passage points’ that knowledge needs to pass through if it is to be accepted and legitimated (Callon 1985) and how these relate to the complex (multi-) institutional environment that provides the backdrop to much construction project working.

CONCLUSIONS

This paper has attempted to provide a broad overview of the ‘practice turn’ in contemporary organizational studies and to relate it to the context of the construction industry and, in particular, to the exploration of issues connected with innovation, knowledge, learning and change. In doing so, the paper has suggested an agenda for research in which several diverse perspectives within a practice-based approach might be deployed more fully to gain a greater understanding of construction management processes, issues and problems. At the same time, however, it is recognized that the ontological and epistemological implications of a practice-based approach pose significant challenges to established construction management theories and research methods. Nevertheless, it is proposed that applying such ideas presents interesting and worthwhile avenues for theory and research, as well as opportunities for generalizing insights gained about construction project organization to wider domains of practice.

REFERENCES

Bechky, B A (2003) Sharing meaning across occupational communities: the transformation of understanding on a production floor. *Organisation Science*, **14**(3), 312-30.

Bendixen, M and Kock, C (2007) Negotiating visualisations in briefing and design. *Building Research and Information*, **35**(1), 42-53.

Blackler, F (1993) Knowledge and the theory of organizations: organizations as activity systems and the reframing of management. *Journal of Management Studies*, **30**(6), 863-84.

Blackler, F, Crump, N and McDonald, S (2000) Organising processes in complex activity networks. *Organisation*, **7**(2), 277-300.

Boland, R J and Tenkasi, R V (1995) Perspective making and perspective taking in communities of knowing. *Organization Science*, **6**(4), 350-372.

Bordieu, P (1977) *Outline of a theory of practice*. Cambridge: Cambridge University Press.

Bordieu, P (1990) *The logic of practice*. Cambridge: Polity Press.

Bresnen, M (2006a) Conflicting and conflated discourses? Project management, organisational change and learning. *In*: D Hodgson and S Cicmil (Eds.) *Making projects critical*. Basingstoke: Palgrave Macmillan.

Bresnen, M (2006b) Keeping it real: the rise (and fall?) of partnering as a boundary object in construction. *In:* Kreiner, K (Ed.), *Micro-processes of Managing the Construction of Buildings*, 16-17 November, Copenhagen Business School.

Bresnen, M, Edelman, L, Newell, S, Scarbrough, H and Swan, J (2003) Social practices and the management of knowledge in project environments. *International Journal of Project Management*, **21**(3), 157-66.

Bresnen, M, Goussevskaia, A and Swan, J (2005a) Implementing change in construction project organisations: exploring the interplay between structure and agency. *Building Research and Information*, **33**(6), 547-60.

Bresnen, M, Goussevskaia, A and Swan, J (2005b) Organizational routines, situated learning and processes of change in project-based organizations. *Project Management Journal*, **36**(3), 27-41.

Brown, J S and Duguid, P (2001) Knowledge and organization: a social-practice perspective. *Organization Science*, **12**(2), 198-213.

Bryman, A and Bell E (2007) *Business research methods*. 2ed. Oxford: Oxford University Press.

Callon, M (1985) Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *In*: J Law (Ed.) *Power, action and belief: A new sociology of knowledge*. London: Routledge and Kegan Paul.

Carlile, P (2004) Transferring, translating and transforming: An integrative framework for managing knowledge across boundaries. *Organization Science*, **15**(5), 555-68.

Contu, A and Willmott, H (2003) Re-embedding situatedness: the importance of power relations in learning theory. *Organization Science*, **14**(3), 283-96.

DeFillippi, R J and Arthur (1998) Paradox in project-based enterprises: the case of filmmaking. *California Management Review*, **40**(2), 125-40.

Foucault, M (1980) *Power/knowledge*. (ed. C. Gordon). Hemel Hempstead: Harvester Wheatsheaf.

Gann, D M (2000) *Building innovation: complex constructs in a changing world*. London: Thomas Telford.

Gann, D M (2001) Putting academic ideas into practice: technological progress and the absorptive capacity of construction organisations. *Construction Management and Economics*, **19**(3), 321-30.

Gherardi, S and Nicolini, D (2003) To transfer is to transform: The circulation of safety knowledge. *In*: D Nicolini, S Gherardi and D Yanow (Eds.) *Knowing in organisations: A practice-based approach*. London: M E Sharpe.

Gibbons, M, Limoges, L, Nowotny, H, Schwartman, S, Scott, P and Trow, M (1994) *The new production of knowledge. The dynamics of science and research in contemporary societies*. London: Sage.

Giddens, A (1990) *The consequences of modernity*. Stanford, CA: Stanford University Press.

Grey, C (2001) Re-imagining relevance: A response to Starkey and Madan. *British Journal of Management*, **12**, S27-S32.

Harty, C (2005) Innovation in construction: a sociology of technology approach. *Building Research and Information*, **33**(6), 512-522.

Knorr-Cetina, K (1999) *Epistemic cultures: How the sciences make knowledge*. Cambridge, MA: Harvard University Press.

Latour, B (1986) The power of association. *In*: J Law (Ed.) *Power, action and belief: A new sociology of knowledge*. London: Routledge and Kegan Paul.

Lave, J and Wenger, E (1991) *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Law, J (1992) Notes on the theory of the actor-network: ordering, strategy and heterogeneity. *System Practice*, **5**(4), 379-93.

Lindkvist, L (2005) Knowledge communities and knowledge collectivities: a typology of knowledge work in groups. *Journal of Management Studies*, **42**(6), 1189-210.

Nicolini, D, Gherardi, S and Yanow, D (2003) *Knowing in organisations: a practice-based approach*. London: M E Sharpe.

Orlikowski, W (2002) Knowing in practice: enacting a collective capability in distributed organizing. *Organization Science*, **13**(3), 249-73.

Pettigrew, A (2001) Management research after modernism. *British Journal of Management*, **12**, S61-S70.

Phua, F T T (2004) The antecedents of cooperative behaviour among project team members: an alternative perspective on an old issue. *Construction Management and Economics*, **22**(10), 1033-45.

Powell, W, Koput, W and Smith-Doerr, L (1996) Interorganisational collaboration and the locus on innovation: networks of learning in biotechnology. *Administrative Science Quarterly*, **41**(1), 116-30.

Sapsed, J and Salter, A (2004) Postcards from the edge: local communities, global programs and boundary objects. *Organization Studies*, **25**(9), 1515-34.

Schatzki, T R, Knorr-Cetina, K and von Savigny, E (2001) *The practice turn in contemporary theory*. London: Routledge.

Starkey, K and Madan, P (2001) Bridging the relevance gap: Aligning stakeholders in the future of management research. *British Journal of Management*, **12**, S3-S26.

Suchman, L (2000) Organising alignment: a case of bridge-building, *Organization*, **7**(2), 311-27.

Swan, J and Scarbrough, H (2005) The politics of networked innovation. *Human Relations*, **58**(7), 913-43.

Tsoukas, H and Chia, R (2002) On organizational becoming: rethinking organizational change. *Organization Science*, **13**(5), 567-82.

Van de Ven, A H and Johnson, P E (2006) Knowledge for theory and practice. *Academy of Management Review*, **31**(4), 802-21.

Wenger, E (1998) *Communities of practice: learning, meaning and identity*. Cambridge: Cambridge University Press.

Whyte, J K, Ewenstein, B, Hales, M and Tidd, J (2007) Visual practices and the objects used in design. *Building Research and Information*, **35**(1), 18-27.

Winch, G M (1998) Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research and Information*, **26**(5), 268-79.

CONSTRUCTABILITY INNOVATION IN PIPE RACK DESIGN FOR REFINERY PROJECT

Bambang Trigunarsyah[1], Erman Surya Bakti[2] and Muhd. Z A Majid[2]

[1]*School of Urban Development, Queensland University of Technology, 2 George Street, GPO Box 2434, Brisbane, Queensland 4001, Australia*
[2]*Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor Darul Takzim, Malaysia*

Increased competitiveness in the construction industry requires the improvement of a construction company's capabilities to combine quality with economic and schedule aspects. Many studies and procedures in quality improvement focus on project quality improvement techniques and efficiency such as total quality management, value engineering, designability, contractability, constructability, operability, maintainability and other quality improvement techniques. This research focuses on constructability, which is the optimum use of construction knowledge and experience in planning, engineering, procurement and field operation to achieve overall project objectives. A case study was performed at an Indonesian refinery project, which applied the design and build type of contract. The case study aims to discuss and analyse the implementation of constructability innovation in the planning and design stage of the refinery project, focusing on optimization and improvement of pipe rack structure. The case study shows that the implementation of constructability during the planning and design stage increased the project performance and reduced the project cost.

Keywords: constructability, design and build, industrial plant, pipe rack, refinery project.

INTRODUCTION

Increased competitiveness in the construction industry requires the improvement of a construction company's capabilities to combine quality of materials and construction works with economic and schedule aspects. Many studies and procedures in quality improvement focus on project quality improvement techniques and efficiency such as total quality management, value engineering, designability, contractibility, constructability, operability, maintainability and other quality improvement techniques. Early involvement of construction knowledge and experience reduce the likelihood of creating designs that cannot be efficiently built, thereby reducing design rework, improving project schedule and establishing construction cost saving (Russell 1994).

In the US, the Construction Industry Institute (CII 1998) has developed 17 constructability concepts, which are grouped under the three main phases of project life cycle, viz. conceptual planning, design and procurement, and field operations. Those concepts were based on the experience of the owners and contractors represented on the CII Constructability Task Force, and the findings of researchers directed by the task force. The main purpose of the concept is to stimulate thinking about constructability and how to make it work. The second CII Constructability Task

[1] bambang.trigunarsyah@qut.edu.au

Force appended three additional concepts, two for the planning phase and one for the design and procurement phases (Russell *et al*. 1992).

The concept of constructability in the US (or buildability in the UK) emerged in the late 1970s. It evolved from studies into how improvements could be achieved to increase cost efficiency and quality in the construction industry. It is an approach that links the design and construction process. It became the subject of a number of research works in the 1980s (Sidwell 1996). Constructability is the capability of a construction project to be constructed. A constructability programme is the application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, design, procurement, construction, test and start-up phases by knowledgeable, experienced construction personnel who are part of a project team. The programme’s purpose is to enhance the project’s overall objectives (ASCE CM Committee 1991). Constructability is also defined as the ability of a project condition to enable the optimal utilization of construction resources (O’Connor 1986b).

The constructability concept was born out of the realization that designers and contractors see the same project from different perspectives, and that optimizing the project requires that the knowledge and experience of both parties be applied to project planning and design processes (Gibson *et al.* 1996). However, many owners, engineers, and contractors are still not aware of the potential benefits of improved constructability. Opportunities to reduce the schedule, improve the functionality of the final product and reduce costs are lost when construction is separated from planning and engineering (CII 1996).

Constructability input is needed because of the high technical complexity of today’s projects and the ever-increasing demands for faster and lower cost delivery of finished facilities (Fischer 1997). But collecting constructability improvement ideas is not an easy task. It requires perseverance on the collector’s part and often alternative thought processes for those providing the ideas. Designers are asked to think like constructors and constructors are asked to think like designers (O’Connor 1986a).

O’Connor (1988) found that the constructability is enhanced when innovative construction methods are utilized. The innovative construction methods refer to methods that are not generally considered common practice across the industry and which are often creative solutions responsive to field challenges. Innovative construction methods may involve:

1. innovative definitive sequencing of field tasks;
2. innovative uses of temporary construction material/systems;
3. innovative uses of hand tools;
4. innovative uses of construction equipment;
5. constructor-optional pre-assembly;
6. innovative temporary facilities directly supportive of field methods;
7. post-bid constructor preferences related to the layout, design and selection of permanent materials.

A new design and technology may be ‘a tool’ which the company can sustain in the construction industry. Innovation can provide the company with a competitive strategy to achieve the project and company objectives. But, on the other hand, construction innovations can produce certain risks associated with their use. The construction companies can use different approaches and strategies to effectively implement design innovation, based on their limited resources. Innovation is defined as a non-trivial improvement in a product, process or system that is actually used and which is novel to the company developing or using it (Marquis 1998, cited in Slaughter 2000).

The most informal constructability programme consists only of a set of checklists used by construction personnel to review design documents for completeness, errors and omissions. This programme is less effective than proactive formal programmes because construction knowledge and experience is provided in a reactive manner. Suggestions made by construction personnel often require redesign. The required redesign can contribute to an adversarial relationship between designers and constructors, as well as increase design cost and the project's schedule (Russell 1993).

Research findings (Tatum *et al*. 1986) suggested that the decisions made during conceptual planning have a major impact during the remainder of the project, particularly on the construction or the constructability of the project. The research indicated that the involvement of those who have construction knowledge and experience in this phase could provide information for critical decisions in the following three areas:

1. *Project planning*. Consideration of construction in the planning phase can result in two types of construction benefits: managerial benefit by having an efficient construction work plan as a result of sequences and schedules for completion of the design that better fit construction needs; and technical benefit by providing design concepts, criteria and approaches that make the final design easier to build.
2. *Site layout*. Consideration of the effect of the site layout on construction input can identify and avoid, generally with only minor changes in the original design concept, many types of construction problems, and thereby promote efficient construction.
3. *Selection of construction method*. Consideration of the construction method during the conceptual planning phase offers a major opportunity for improvement of constructability, thereby overcoming major technical challenges and avoiding high-risk operations. It is also a means of cost reduction.

This case study presents the implementation of a constructability programme within a refinery project, focusing on design process and changing innovation from the existing conventional design based on the constructability concept. Informal constructability programmes are developed to facilitate interdisciplinary communication between construction and design engineering personnel.

RESEARCH METHOD

The aim of this research is to study the implementation of constructability innovation at the project level. Early involvement of construction knowledge and experience (constructability aspects) at the planning and design phase will increase a project's performance (CII 1986; O' Connor 1987; Russell 1994). A case study was the preferred method of this research, as it studied contemporary events, but with the relevant behaviour unable to be manipulated (Yin 1994). This paper is a continuation study from Trigunarsyah (2004).

The purpose of this paper is to describe a process of technological innovation within the construction firm and to develop implications for increasing its rate. In this research, construction technology is defined as the combination of construction method, construction resources, work tasks, and project influence that defines the manner of performing a construction operation (Tatum 1987b). Innovation is the first use of technology within construction firms (Construction 1981, cited in Tatum, 1987b).

O'Connor (1987) performed the research and explored the CII constructability concepts for the design phase. The format for each concept is comprised of three parts: (1) statement of the concept; (2) discussion of the concept; and (3) specific application of the concept. The simplified concepts are focusing on (1) construction-driven schedules; (2) simplified design configurations; (3) standardization of the elements; (4) module/pre-assembly designs which facilitate fabrication, transport and installation; (5) accessibility and adverse weather.

Project performances are measured from constructability benefit parameters that are presented by Russell (1994b), where the benefit can be either quantitative or qualitative as seen Figure 1.

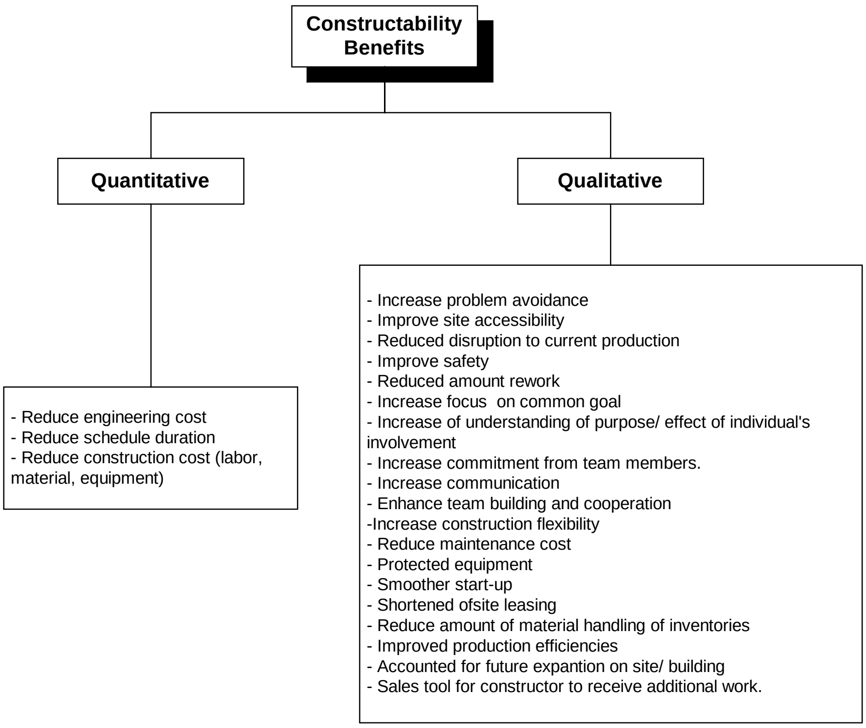


Figure 1: Framework for determining constructability benefit (Russell 1994)

Slaughter (2000) found the six stages of implementation for innovation often identified in theoretical literature and empirical studies are: (1) identification; (2) evaluation; (3) commitment; (4) detailed preparation; (5) actual use; (6) post-use evaluation, as seen in Figure 2.

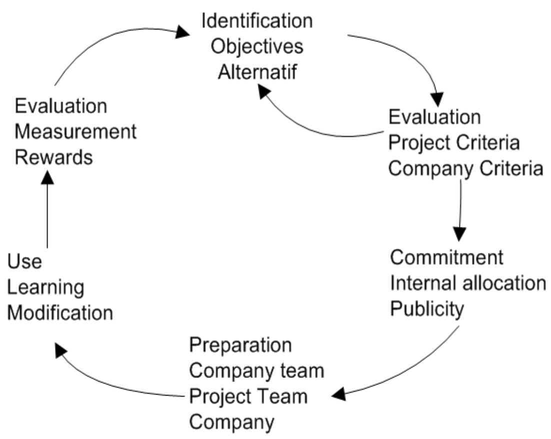


Figure 2: Implementation stages for innovation (Slaughter 2000)

A critical factor for the identification stage is the presence of a person within the company who is aware of potential solutions that might be applicable to the problem at hand (Slaughter 2000).

The parameters of constructability for this research are a combination of the implementation of CII constructability concepts at the planning (eight concepts), design and procurement (eight concepts) stages only, and focusing on specific application of constructability already studied by O'Connor (1987). The parameters are as follows:

1. early involvement of construction personnel (or knowledge and experiences);
2. overall project schedules are construction sensitive;
3. modularization and pre-assembly;
4. standardization;
5. simplified design configuration; and
6. construction method and innovation.

The constructability implementation checklists for this innovation were developed from constructability improvement classifications by O'Connor (1986b).

PROJECT DESCRIPTION AND BACKGROUND

The project selected for this case study was the engineering, procurement, construction and commissioning (EPCC) of the refinery plant in Balongan, Indonesia. The construction cost was about US$152 million and the contract duration was 25 months for mechanical completion and 27 months for operational acceptance, commencing in 2003 and completed in 2005. The contractor is a consortium of PT Rekayasa Industri (as a leader) and Toyo Engineering Corporation. The contract type is design and build.

PT Rekayasa Industri, an Indonesian state-owned construction company, which specializes in industrial-type construction projects, was selected as the case study. PT Rekayasa Industri's involvement in construction projects includes conceptual planning, engineering design, procurement, construction (or EPC) construction and project management services. This company has experience of projects of a size up to

US$250 million for EPC projects. Implementation of constructability improvement performed by PT Rekayasa Industry was based on the concepts of constructability developed by the CII.

The project was chosen as a case study because: it is a prestigious refinery projects conducted by a local Indonesian contractor; it is a design and built project, as most construction projects in industrial plant, was schedule driven, and most of the engineering activities overlap with procurement and construction, and some portion of the work is in potentially hazardous conditions; the diverse complexities of the scope of project, and multi-disciplinary involvement; the third writer was highly involved in the project during the planning and design stage and as advisor during the construction stage.

PROJECT CONSTRUCTABILITY IMPLEMENTATION

The awareness of constructability benefits can enable senior managers to make more informed decisions regarding the early involvement of construction knowledge and experience in the conceptual planning and design stage of this project.

Business considerations resulted in a scheduled total duration of 25 months. Based on the refinery plant average, a project of this size and scope is usually expected to take 30 to 36 months. Contractor project participants partially attribute the achievement of the project duration to the commitment to implementing the constructability concept.

During the bidding stage, the changing needs of the contractor and competition in construction competitive strategy purposes, led the contractor to propose the technological innovation alternative design based on the constructability implementation concept. This concept is primarily directed towards constructor organization. As discussed in the constructability concept file (CII 1986), the design and built contract method can enhance the constructability innovation, because the constructor preferences are identified early on, prior or during bidding stage, and are effectively treated during design and procurement and reflected in the initial issue of drawings and specifications. Under such ideal circumstances, 'design breakage' is minimal and the preferences are given full consideration by the designer with construction personnel.

This paper will discuss one of the constructability innovations that was proposed during the bidding stage. The innovation was: to change the steel pipe rack with concrete fire proofing into precast concrete pipe rack. The increase in steel price was one of the reasons why the contractor proposed this concept. A precast concrete pipe rack was a significant schedule and cost improvement concept incorporated early in the design effort. This precast concrete pipe rack concept was discussed with the engineers during the proposal stage.

Commitment for the precast concrete pipe rack innovation is needed from the parties responsible for achieving the objectives, such as contractor management, multidisciplinary design engineers, construction experts, site construction engineers, with approval from the owner, to reduce the degree of risk associated with the change. Once the precast concrete pipe rack decision was made, the multidisciplinary engineers worked closely to the precast concrete pipe rack concept and prioritized sequencing of engineering to ensure the idea could be carried out.

The company carried out incremental innovation to reduce risk and impact in the design and construction stages. The precast concrete pipe rack was developed by an organization with specific expertise, capability and control in implementation. The precast concrete pipe rack was evaluated with respect to the module it replaced and the risk associated with the design change within conceptual development design. The incremental innovation design process can be seen in Figure 3.

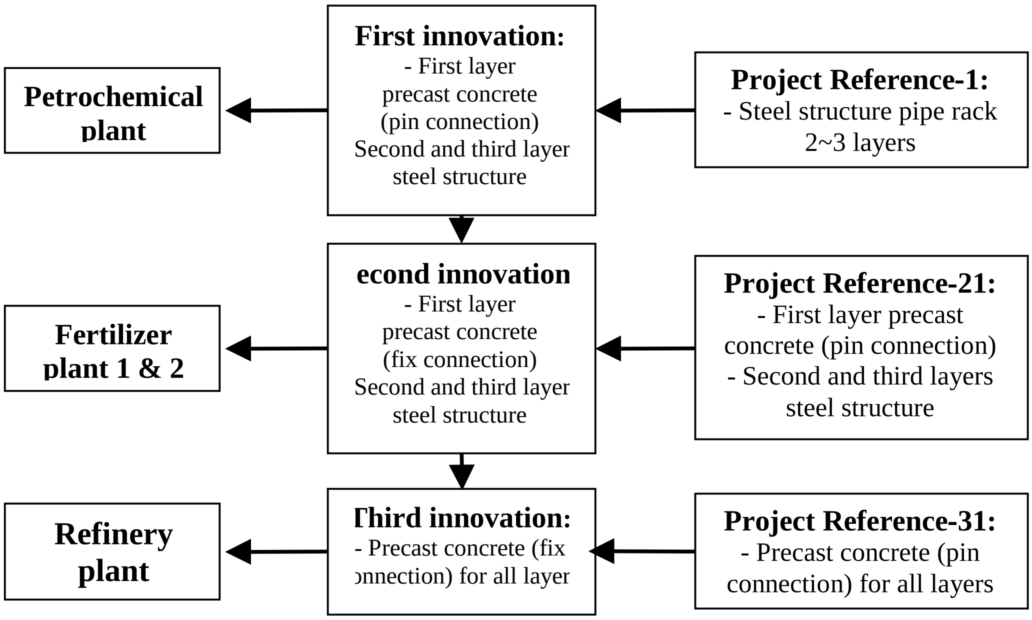


Figure 3: Innovation process for precast concrete pipe rack

The precast concrete pipe rack significantly affected the typical engineering and construction methodology of process designing from the process areas to the pipe rack. The design engineer had to assume and analyse a higher degree of risk associated with early sizing especially in piping and mechanical equipment layout drawings. There was an increase in design effort attributed to this practice due to the increased risk. The increase of rework can be avoided; however, as that problem can be anticipated early in the construction planning.

The safety and productivity were enhanced owing to the precasting work, thus the amount of work performed on scaffolding was reduced and medium cranes were used to erect the precast columns and beam simultaneously. The early site installations of the pipe rack columns also enhance safety and productivity, because the site activities can be focused on civil work only without any other disciplines involved. The complexity and risk of installation can be reduced.

The effective sequencing and repetitive activity in achieving enhanced the constructability. The benefits are particularly significant for the installation of the pipe rack itself, piping, electrical, instrumentation and mechanical equipment. Early installation of a precast concrete pipe rack can serve to minimize congestion and keep access routes open. The precast concrete method can also reduce the use of scaffolding.

Especially for the connection detail of the pipe rack the contractor hired a specialist from the university. The typical detailed precast concrete fix connection was filled with non-shrink cement grout.

The maximum length of column was 15 metres with maximum weight of precast concrete column 15 ton. For installation purposes, the main crane used had 60 ton capacity, and 30 ton capacity for the tailing crane. The cranes were used simultaneously with underground piping, above ground and mechanical equipment installation. Construction equipment shared by several activities increased the work productivity. The choice of precast method can also reduce the likelihood of delays in provision of utilities, and can improve the construction work environment especially with regard to weather conditions and the use of scaffolding.

During implementation of the project constructability innovation, the documented design process and implementation of the lesson learned for this pipe rack was described as follows:

1. Assign personnel as constructability champion to do the comparison study for specific precast concrete pipe rack.
2. Collecting the project lesson learned.
3. Preliminary concept design and construction method (technical pre-planning).
4. Brainstorming session with all project team and university.
5. Collecting the design and construction impact from multidisciplinary engineers.
6. Selection and distribution of priorities of the constructability decision (endorsed by management).
7. Transportation and procurement analysis.
8. Prepare the realistic EPC planning and schedule, based on limited resources.
9. Design concept approval from owner.
10. Optimization of design based on constructability concept.
11. In-house detail design.
12. Subcontracting of precast prefabrication and installation.
13. Presenting the detail sequence of pipe rack to subcontractor key personnel.
14. Controlling and monitoring of construction.

During detail design, all aspects of the constructability were analysed and exercised carefully. Fabrication method, transportation requirements and sequence of installation with three-dimensional analysis were prepared as seen in Figure 4.

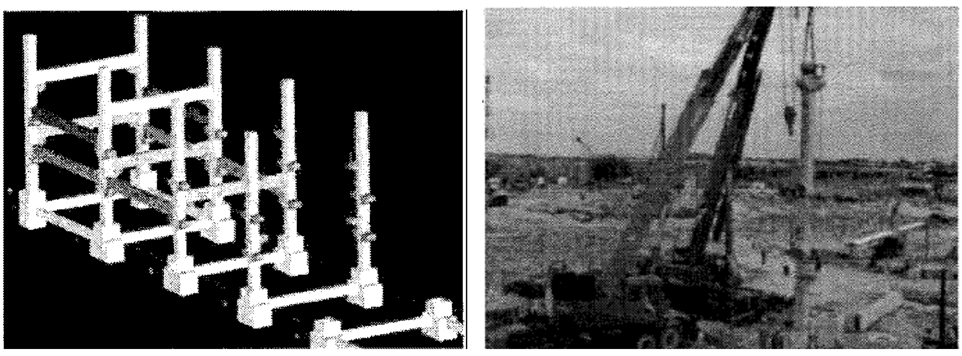


Figure 4: Precast concrete column beam: three-dimensional planning and installation

The installation of the precast concrete pipe rack was performed based on detailed sequence procedures already prepared during concept planning.

At completion of the project, the documented cost saving in this precast concrete pipe rack was 30.52%. The qualitative benefits of this constructability innovation also include reducing the schedule, increase of focus on common goal, increase in understanding of purpose/effect of individual involvement, increased commitment from team members, improvement in quality, site accessibility, safety enhancement, and better control of risk. Early efforts of construction activities can reduce the project schedule and congestion of the area during peak load of project. And the important factor is: the early efforts of constructability implementation can oblige the engineer to make the best efforts at each stage of the project. A comparison of major volume difference between the precast concrete and steel structure pipe rack is shown in Table 1.

Table 1: Major volume comparison of precast concrete and steel structure pipe rack

No.	Description	Quantity	Volume	
			Precast pipe rack	Steel pipe rack
1	Concrete foundation	M3	610	600
2	Concrete precast	M3	1770	—
3	Steel structure	Ton	—	710
4	Concrete fire proofing	M3	Included	240

CONCLUSION

This research has found that documented cost saving in this precast concrete pipe rack is 30.52%. The qualitative benefits of this constructability innovation also include reducing the schedule, increase of focus on common goal, increase in understanding of purpose/effect of individual involvement, increased commitment from team members, improvement in quality, site accessibility, safety enhancement, and better control of risk. Early efforts of construction activities can reduce the project schedule and congestion of the area during peak load of the project. And the important factor is: the early efforts of constructability implementation can oblige the engineer to make the best efforts at each stage of the project.

Lessons learned are indicated as primary factors in implementation of constructability. The case study shows that constructability implementation can result in innovation and improve the project performance. Early involvement of construction knowledge and experienced personnel, and standardization of design are the most influential factors of constructability implementation in increasing project performance and reduction of the project cost.

REFERENCES

ASCE CM Committee (1991) Constructability and constructability programs: White Paper. *ASCE Journal of Construction Engineering and Management*, **117**(1).

CII (1998) *Constructability: a primer*, cited in Ryan, R H *Implementing project constructability*. Participant Handbook, CII.

Fischer, M (1997) Characteristics of design-relevant constructability knowledge. *ASCE Journal of Construction Engineering and Management*, **123**(3).

Gibson, G E, McGinnis, C I, Flannigan, W S and Wood, J E (1996) Constructability in public sector. *ASCE Journal of Construction Engineering and Management*, **122**(3).

Gugel, J G and Radtke, M W (1994) Model for constructability approach selection. *ASCE Journal of Construction Engineering and Management*, **120**(3).

Mendelsohn, R (1997) The constructability review process: a constructor's perspective. *ASCE Journal of Management in Engineering,* May/June.

O'Connor, J T (1986a) Collecting constructability improvement ideas. *ASCE Journal of Construction Engineering,* **112**(4).

O'Connor, J T (1986b) Industrial project constructability improvement. *ASCE Journal of Construction Engineering and Management*, **112**(1).

O'Connor, J T (1987) Constructability concepts for engineering and procurement. *ASCE Journal of Construction Engineering and Management*, **113**(2).

O'Connor, J T and Miller, S J (1994) Constructability programs, method for assessment and benchmarking. *Journal of Performance of Constructed Facilities,* **8**(1).

O'Connor, J T and Victoria, S D (1988) Constructability improvement during field operations. *ASCE Journal of Construction Engineering and Management*, **114**(4), 548–64.

Russell, J S *et al.* (1993) Documented constructability savings for petrochemical-facility expansion. *ASCE Journal of Performance of Constructed Facilities*, **8**(7).

Russell, J S *et al*. (1994) Constructability related to TQM, value engineering & cost/benefit. *ASCE Journal of Performance of Construction Facilities*, **8**(1).

Russell, J S, Gugel, J G *et al*. (1994b) Comparative analysis of three constructability approaches. *ASCE Journal of Construction Engineering and Management,* **120**(1).

Sidwell, A C and Francis, V E (1996) *The application of constructability principles in the Australian construction industry: shaping theory and practice*. Vol. 2. E & FN Spon.

Slaughter, E S (2000) Implementation of construction innovations. *Building Research & Information*, **28**(1), 2–17.

Tatum, C B, Venegas, J A and William, J M (1987) Improving constructability during conceptual planning. *ASCE Journal of Construction Engineering and Management*, **113**(2).

Tatum, C B (1987) Process of innovation in construction firm. *ASCE Journal of Construction Engineering and Management*, **113**(4).

Trigunarsyah, B (2004) Constructability practices among construction contractors in Indonesia. *ASCE Journal of Construction Engineering and Management*, **130**(5).

Trigunarsyah, B (2001) *Implementation of constructability improvement into the Indonesian construction industry*, Unpublished PhD Thesis, Department of Civil and Environmental Engineering, The University of Melbourne.

Yin, Rt K (1994) *Case study research design and methods*. California: Sage.

CURRENCY CONVERSIONS FOR CONSTRUCTION COST COMPARISONS: PURCHASING POWER PARITIES AND EXCHANGE RATES

Rick Best[1]

School of Built Environment, University of Technology Sydney, 702-730 Harris Street, Ultimo, NSW, Australia

The method used to convert construction costs to a common currency can have significant effects on the results obtained from comparative studies. The relationship between purchasing power parities (PPPs), both general and construction-specific, and market exchange rates with respect to the Australian dollar and three other major currencies was examined over the period 1990–2003. Trends over time were identified using linear regression and it was shown that there is little consistency in the relationship between general PPPs, average exchange rates and other indices. This highlights the need for reliable industry-specific conversion factors as currently there is no method available that can be shown to be more reliable than any other, and studies that do not include rigorous testing of the conversion approach used must produce questionable results.

Keywords: construction costs, exchange rates, international comparisons, purchasing power parity.

INTRODUCTION

Comparisons of construction industry performance, whether based on cost, productivity, projects or whole industry sectors, are notoriously difficult yet they are regularly attempted. A fundamental problem with virtually all such comparisons is the necessity to express all financial data (typically construction costs) in some common base currency, such as USD. Best and Langston (2006a, 2006b) show that the method used to make such cost conversions can have significant effects on the outcomes of comparative studies and their studies highlight the importance of using appropriate conversion methods if reliable results are to be obtained.

The aim of this paper is to extend that work by examining 10-year average exchange rates between several countries and comparing them to published purchasing power parities, both GDP level and construction specific, over a number of years in order to compare fluctuations in outcomes in respect of the various conversion methods used.

EXCHANGE RATES AND PURCHASING POWER

There is wide agreement that the use of exchange rates *per se* is not a sound method for converting costs (e.g. Goodchild and Griffiths 2004; Lafrance and Schembri 2002; ABS 2002; McKinsey 1995) as they are too volatile and are affected by a range of

[1] rick.best@uts.edu.au

influences that are not related to the relative value of currencies (e.g. Blake *et al*. 2006; Pilat 1996b).

Many argue that purchasing power parities (PPPs) provide a better basis for comparing financial data between countries as these conversion factors compare the value of monetary amounts based on the purchasing power of currencies in their respective countries and thus eliminate underlying differences in price levels (Al-adhadh 2002; Schreyer and Koechlin 2002; Ong 2003). It is often noted, however, that GDP level or general PPPs are not suitable for converting financial data at the level of individual industries (Pilat 1996a; Schreyer and Koechlin 2002; Stapel 2002; Goodchild and Griffiths 2004), and that there are few such industry-specific PPPs available.

Some construction-specific PPPs (CPPPs) are published but for a relatively small group of countries (European Union and OECD countries generally) and these are considered, for a variety of reasons, not to be very reliable (Vermande and van Mulligen 1999; Ive *et al.* 2004; Blake *et al.* 2006). The current method for gathering construction cost data for PPPs requires cost experts in each respondent country to price comprehensive bills of quantities for a number of ‘standard projects’; this raises many questions including the lack of familiarity with the BQ approach in many countries, problems associated with finding projects that are both comparable and yet representative of local practice, the expense that is incurred in hiring construction cost consultants to provide specialist knowledge (which results in only a single set of prices being obtained in each country) and problems of different interpretation of the pricing documents. The standard projects method is intended to gather out-turn costs (i.e. what the client actually pays) and therefore is designed to include mark-ups, labour/capital mix and other potential problems, but inconsistencies in pricing that are revealed by the extensive validation exercises that are routinely carried out by Eurostat (for instance) in pricing rounds for PPP production are one of the major reasons for the current distrust of the CPPPs that result.

While the search for methods that will produce more reliable CPPPs is ongoing (e.g. Walsh and Sawhney 2002; Meikle 2002), some (e.g. Langston and de Valence 1999) have applied other methods such as the Big Mac Index, published by *The Economist*, in attempts to address the problems associated with availability of suitable PPPs.[RB1]

Previous studies

One of the studies revisited by Best and Langston was carried out in 1993 (Lynton 1993); in that study a real office building project in the UK was priced, under several scenarios, in the US and the estimated costs compared to the actual costs of the UK project. The Lynton team used 10-year average exchange rates as the basis for currency conversion and then, using that as a starting point, identified Charlotte NC as a location where US input costs for a range of common building materials and labour were similar to those current in London at the time the sample project was built. In this way they attempted to eliminate price differences between the two locations, much in the manner that purchasing power parities are used to compare value between different countries with price differences removed (Schreyer and Koechlin 2002; Meikle 1990). The question that this raises, however, relates to whether the use of the 10-year average exchange rate is justified.

Best and Langston compared general PPPs to the 10-year average exchange rate (for GBP and USD) over the period 1990 to 2003, and plotted the available CPPPs against these values (Figure 1).

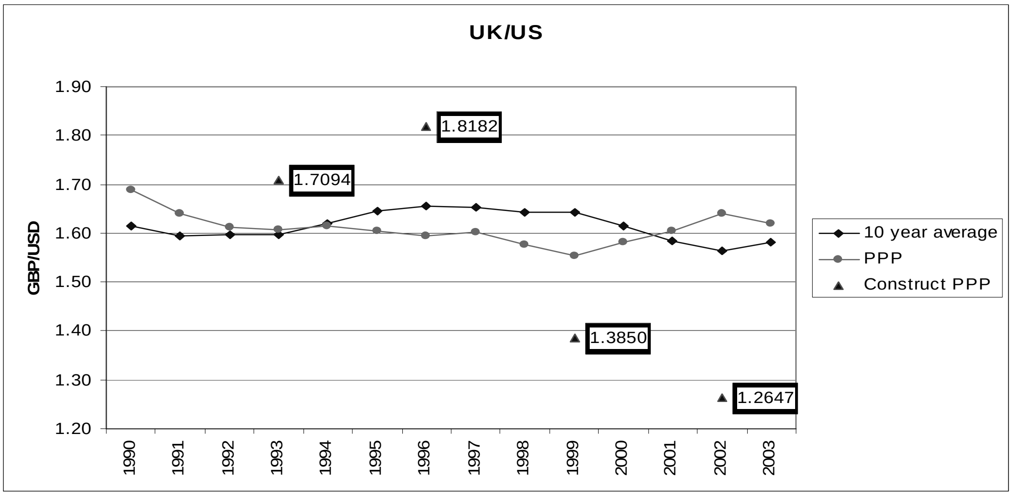


Figure 1: General PPPs, 10-year average money market exchange rates and construction specific PPPs (Best and Langston 2006b)

In 1993, the year of the Lynton study, the general PPP and the 10-year average rate were nearly the same, and the CPPP for that year was only marginally higher. This suggests that for that particular study the comparative costs reported should be sound as regardless of the method adopted to convert construction costs between the two countries the outcomes would be very similar. Furthermore the US costs were estimates and therefore subject to the normal variations of estimates hence small differences in the outcomes resulting from the use of different conversion factors were not considered to be significant.

By 2002, however, larger differences between the various factors are evident; while the general PPP was only around 5% higher than the 10-year average rate it was nearly 30% higher than the CPPP. Had the study been carried out in 2002 and CPPPs been used rather than either of the other options, the outcomes would have been quite different.

The results of two other studies (Flanagan *et al*. 1986 and DISR 1999) were shown to vary markedly depending on the conversion approach adopted (Best and Langston, 2006a). Similarly, in another analysis (Best and Langston 2006b) the use of general PPPs was examined and a reworking of the data reported in a paper by Xiao and Proverbs (2002) produced results notably different from those described by the authors of the original papers.

In the absence of industry-specific PPPs for the construction sector that are accepted as giving reliable comparisons of construction output between countries it may be that long-run average exchange rates may be a useful substitute. The following analysis compares 10-year average exchange rates to general PPPs (from several sources) and, where available, CPPPs and Big Mac indices for several developed countries, viz. the UK, US, Australia and Japan.

METHOD

This study compares conversion factors for Australian dollars and the currencies of three other developed economies: the US, the UK and Japan. The aim of the study was to determine whether there was any apparent consistency between the various conversion factors, and therefore if any one method or combination of methods could be said to produce more consistent or reliable results.

Sources of data

Ten-year average exchange rates were calculated using historical exchange rates (RBA 2007). The average for each year was calculated using either the last value for each quarter in that year, daily rates or monthly rates depending on data availability. Sensitivity tests show that annual averages vary little in relation to the method (daily, monthly or quarterly) that is used. The rolling 10-year average for any given year was calculated from the annual average exchange rate for that year and the preceding nine years.

General PPPs and CPPPs were retrieved from a variety of OECD tables (e.g. OECD 2002; OECD 2005) and the Penn World Tables (PWT 2006); historical Big Mac indices were taken from data files attached to Pakko and Pollard (2003).

The study period is the same as that used for the examination of the Lynton study (Best and Langston 2006b), i.e. 1990 to 2003. Construction PPPs are generally only published by the OECD at roughly three-year intervals while general PPPs are published annually.

As published PPPs express purchasing power relative to a base (USD or a group of countries such as the Eurozone) secondary PPPs between pairs of countries such as Japan and Australia were derived from the USD relative PPPs.

It should be noted that the regression lines shown on the following charts are used only to establish trends over the study period; they should not be interpreted as predictors of future movements.

Exchange rates

The AUD has lost value against all three currencies since 1981. The floating of the AUD in 1983 is reflected in significant drops through the mid-1980s but the general downward trend continued through to 2003 despite some movements against that trend, and some reversal of the trend in the last three years of the study period.

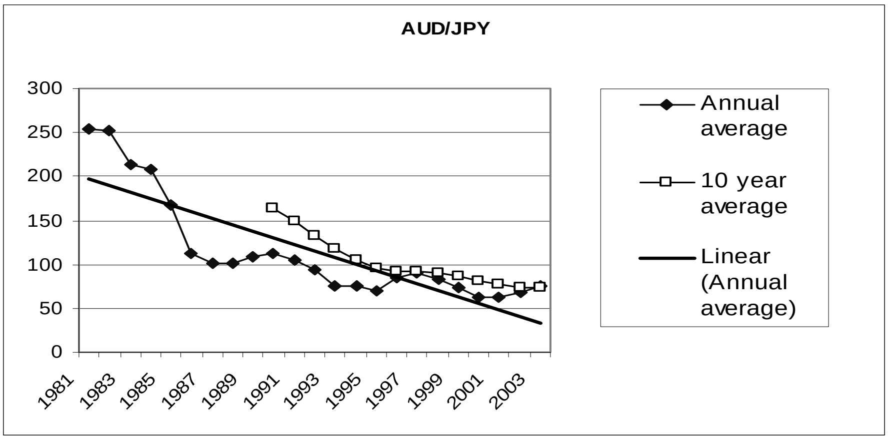


Figure 2: Historical exchange rates: AUD to JPY (RBA 2007)

Ten-year average rates (10YA) for the period 1990 to 2003 smooth out some of the fluctuations but the general downward trend is still evident. Note that the slope of the trendlines in the following three figures are not comparable due to different Y-axis scales.

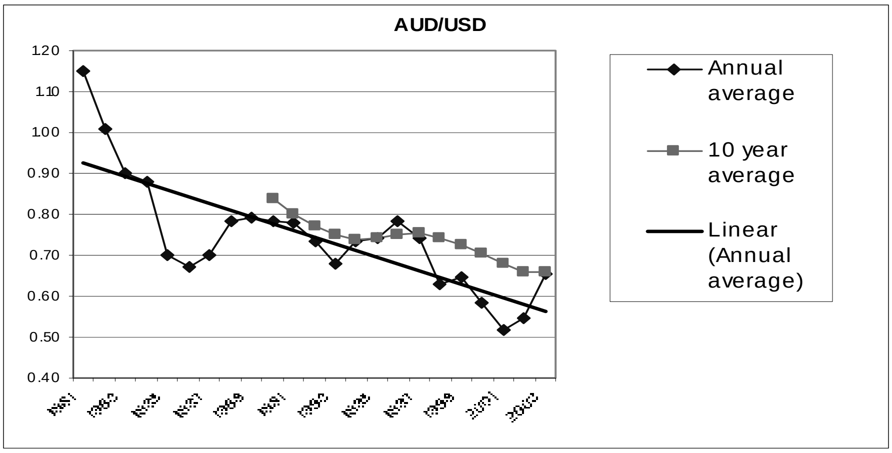


Figure 3: Historical exchange rates: AUD to USD (RBA 2007)

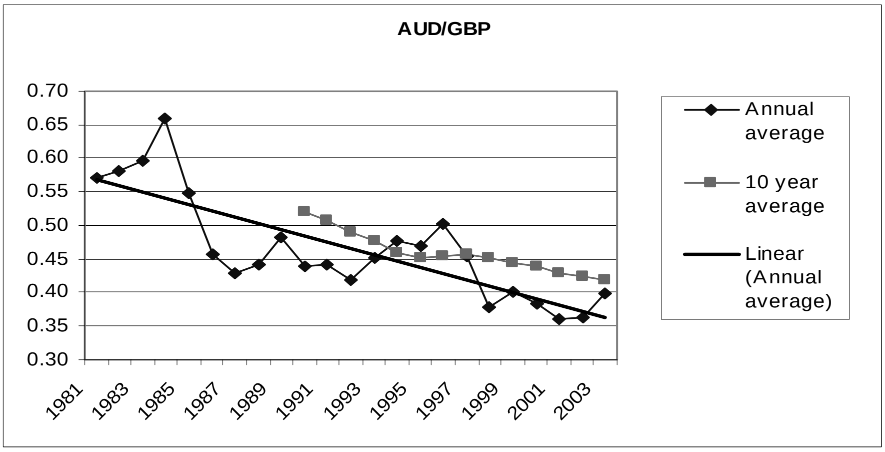


Figure 4: Historical exchange rates: AUD to GBP (RBA 2007)

Bilateral comparisons

The following three figures (Figures 5, 6 and 7) plot a number of conversion factors for the three currencies against the AUD.

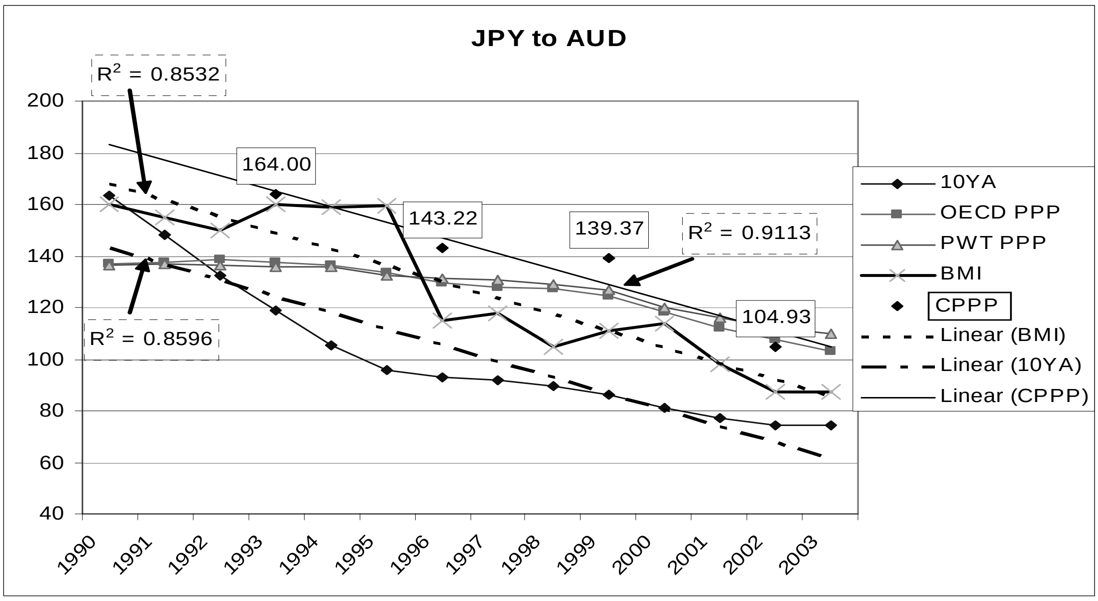


Figure 5: Conversion factors: JPY to AUD

Figure 5 shows the comparison between the Japanese yen and the Australian dollar. The graph prompts several observations about the relationship between the two currencies over the 14-year period and their relative purchasing power.

- The OECD and PWT PPPs are very closely aligned. This is to be expected as the PWT values for these countries are based on original OECD data; the other bilateral comparisons (AUD/USD and AUD/GBP) show similar alignment.
- The purchasing power of the JPY, based on general PPPs has risen by around 20% relative to the AUD.
- The 10YA exchange rate diverges quite substantially from the PPPs and highlights the problems of using exchange rates in comparative studies: while the relative purchasing power of the JPY has risen, the 10YA shows a considerably greater strengthening of the yen against the dollar in the period 1992–2003.
- The Big Mac Index (BMI) follows the same trend but for much of the study period shows more marked fluctuations from year to year.
- CPPPs show a similar trend, but these data are limited.
- Trendlines based on linear regression, all with strong r^2 values, show almost identical slope for the BMI, CPPPs and 10YA.

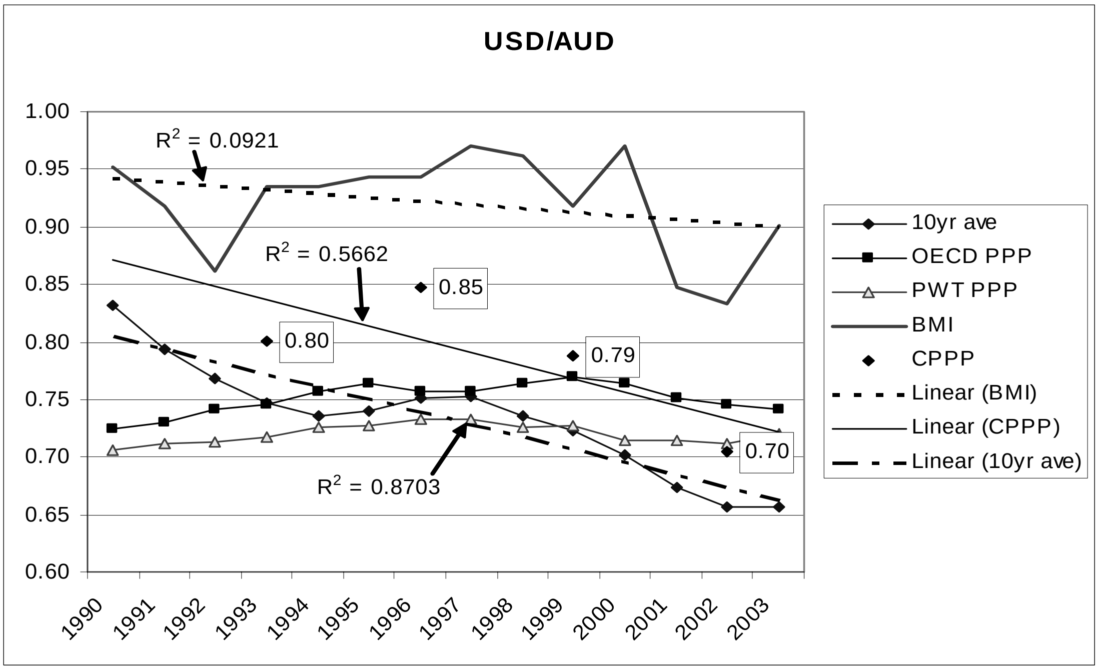


Figure 6: Conversion factors: USD to AUD

Figure 6 shows a similar comparison between the AUD and the USD.

- The OECD and PWT PPPs are fairly stable and reasonably closely aligned although they differ more than those in the previous comparison. The purchasing power of the USD compared to the AUD did not vary greatly from 1990 to 2003.
- The 10YA shows a steady strengthening of the USD against the AUD.

- While the Big Mac Index shows a similar downward trend to the 10YA the decline is not as marked and the BMI shows more marked fluctuations from year to year.
- CPPPs again follow the trend of the 10-year average and at similar slope.

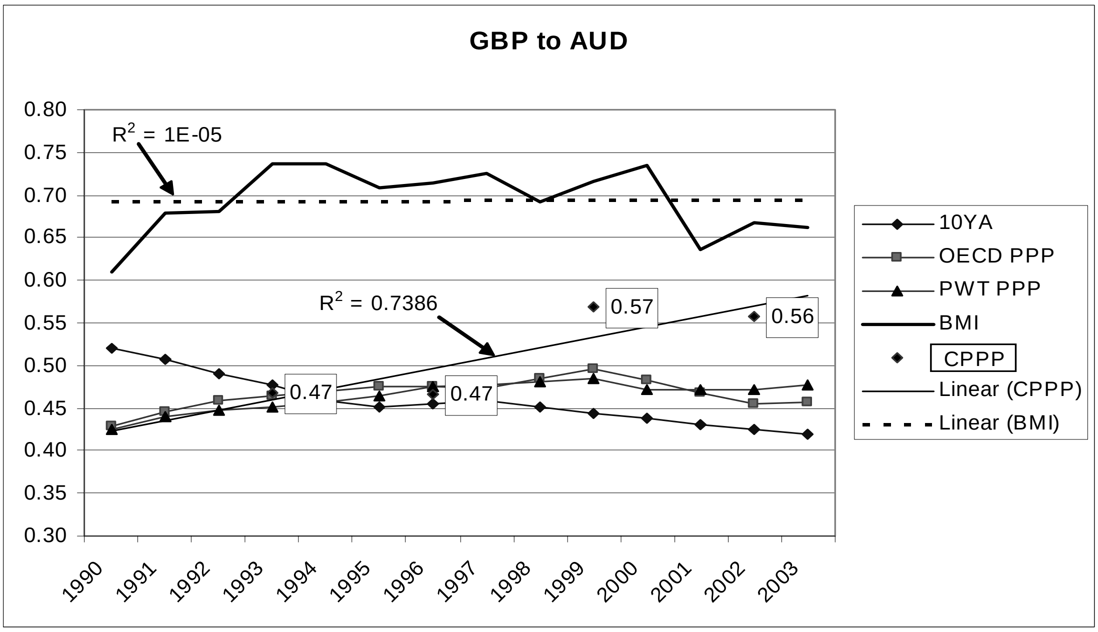


Figure 7: Conversion factors: GBP to AUD

Figure 7 shows the same factors for GBP and AUD. For clarity no trendline is shown for the 10-year average as it almost exactly on the plotline (R^2 = 0.9008).

- The 10YA and both general PPPs converge around 1993 and remain fairly closely aligned and stable through to 2003.
- The Big Mac Index, while suggesting that the AUD is considerably undervalued against the GBP and showing some sharp fluctuations from year to year, shows a nearly horizontal trendline over the 14-year period.
- CPPPs suggest an increase in the purchasing power of the AUD for construction.

ANALYSIS

The three bilateral comparisons tell a mixed story with some consistency apparent but with a number of notable inconsistencies also evident. While the AUD/JPY comparison shows that while numerical relativities for the BMI, CPPPs and the 10YA varied over time they showed nearly identical trends; the USD/AUD comparison showed similar but less closely aligned trends. The GBP/AUD chart, however, shows a different picture altogether with CPPPs moving upward while the 10YA moved down and the BMI showed short-term fluctuations about a nearly horizontal trendline.

There is little in this analysis to suggest that 10YA rates are a more or less reliable method for converting construction costs between countries than other possible methods such as PPPs or hamburgers. As Best and Langston (2006b) noted with regard to the Lynton study (see Figure 1) it was probably no more than good fortune that the 10YA, PPP and CPPP were all closely aligned in 1993. A similar alignment appears in the GBP/AUD comparison from 1993 to 1996 but, as Figure 7 shows, by

1999 and through to 2003 the CPPPs and the other indices (apart from the BMI) move well apart. In contrast, while the USD/AUD chart shows a similar alignment in the 1993–1997 period, and a similar divergence thereafter, the CPPPs move quite differently and show a trendline with a slope that matches that of the 10YA line very closely. The Big Mac Index, although showing some similar trends in the comparisons with JPY and USD, shows quite different implied exchange rates for all three currencies against the AUD.

DISCUSSION

Comparisons such as the AUD/JPY example here, that show numerical relativities varying quite substantially but show very similar trends over time, lend some support to the suggestion made by Langston and Best (2000: 37) that 'international comparisons between developed countries are … not sensitive to PPP adjustment'. That observation was, however, based on comparisons between only the BMI and OECD PPPs, and in that study, as is the case here, the UK was shown to be an exception. It should be noted, however, that as these are linear regressions the percentage change over time and between the different methods will still vary.

Generally speaking the CPPPs in the preceding figures show greater fluctuations than the other indices – this lends some support to the belief that CPPPs, as they are currently produced, are no more reliable than any other method as it is not clear whether these movements are caused by some specific factor such as cyclical variations, or if they are due to the inconsistencies in pricing that were discussed previously.[RB2]

Stapel (2004) advises strongly against the use of general PPPs for industry level comparisons and the BMI is not only much more volatile than the other factors but in two of the three examples shows relative currency values that are markedly higher than those shown by the other measures (with AUD/JPY the exception). It is such exceptions that reinforce the need for reliable construction-specific cost conversion factors as no currently available factor or method can be shown to be consistently better than any other.

CONCLUSIONS

The only sound conclusion that can be drawn from the foregoing analysis and discussion is that, as yet, there is no obvious, consistent result. It appears that reliable industry-specific PPPs are required as there is no great consistency across the other available methods. Current CPPPs, which are, in any case, only available for a limited number of (developed) countries, are treated with caution by most that are active in this area of research yet there appears to be no better alternative currently available; further work may, however, improve their accuracy and increase the range of countries that they cover.[RB3] Reliance on any single method will produce potentially unreliable results, and while it is not yet possible to determine if there is one 'correct' method it appears that some comparison of results obtained using a variety of methods is advisable.

While this study is limited to just three bilateral comparisons, with AUD as the common base, there is considerable diversity in the outcomes; further analysis is required, based on other currency pairs, to ascertain whether similar divergences are evident or if these results are peculiar to the AUD. Similarly further research is required to extend this analysis to developing countries.

REFERENCES

ABS (2002) *Purchasing power parities and real expenditures – 1999 benchmark results for OECD countries*. Australian Bureau of Statistics. Available at www.abs.gov.au/Austats.

Al-adhadh, K (2002) A short appraisal of the experience of the ESCWA region in implementing the international comparison programme (ICP) round in 1996. Paper presented at the Conference on the International Comparison Program, 11–14 March 2002, Washington, DC. Available at www.worldbank.org/data/icp/documents/dms.

Best, R and Langston, C (2006a) Evaluation of construction contractor performance: a critical analysis of some recent research. *Construction Management and Economics*, **24**, 439–45.

Best, R and Langston, C (2006b) Converting construction costs to a common currency base: an unresolved problem. *In*: *Proceedings of Construction in the XXIst Century: Local and Global Challenges*, 18–20 October 2006, CiB, Rome.

Blake, N, Croot, J and Hastings, J (2004) *Measuring the competitiveness of the UK construction industry: volume 2.* Experian Business Strategies. London: Department of Trade and Industry.

DISR (1999) *International cost of construction study. stage one – base cost of construction*, Prepared by Page Kirkland Partnership for Department of Industry Science and Resources, Canberra.

Federal Reserve (2007) Federal Reserve statistical release – foreign exchange rates. Available at www.federalreserve.gov/releases/H10/Hist/.

Flanagan, R, Norman, G, Ireland, V and Ormerod, R (1986) *A fresh look at the UK & US building industries*. London: Building Employers Confederation.

Goodchild, G and Griffiths, D (2004) New Zealand's involvement in the joint OECD–Eurostat Purchasing Power Parities Programme. Statistics New Zealand Information Paper 2004.

Ive, G, Gruneberg, S, Meikle, J and Crosthwaite, D (2004) *Measuring the competitiveness of the UK construction industry, volume 1.* Department of Trade and Industry.

Lafrance, R and Schembri, L (2002) Purchasing-power parity: definition, measurement and interpretation. *Bank of Canada Review*, Autumn, 27–33.

Langston, C and Best, R (2000) *International construction study*. Canberra: Department of Industry Science and Resources. Available at www.industry.gov.au/assets/documents/itrinternet/BC-international_construction.pdf.

Langston, C and de Valence, G (1999) *International cost of construction study – stage 2: evaluation and analysis*. Canberra: Department of Industry Science and Resources, Available at www.industry.gov.au/assets/documents/itrinternet/BC-CoCStage2.pdf.

Lynton (1993) *The UK construction challenge*. London: Lynton plc.

McKinsey (1995) *Growth platforms for a competitive Australia*. Sydney: McKinsey and Company.

Meikle, J (1990) International comparisons of construction costs and prices. *Habitat International*, **14**(2/3).

Meikle, J (2002) Eurostat capital goods price surveys. Unpublished Construction Surveys Discussion Paper.

OECD (2002) *Purchasing power parities and real expenditures – 1999 benchmark year*. Paris: Organisation for Economic Co-operation and Development.

OECD (2005) *PPPs for GDP – historical series*. Available at www.oecd.org/std/ppp/.

Ong, L L (2003) *The Big Mac Index*. Palgrave Macmillan.

Pakko, M and Pollard, P (2003) Burgernomics: a Big Mac guide to purchasing power parity. *Federal Reserve Bank of St. Louis Review*, **85**(6), 9–28.

Pilat, D (1996a) Labour productivity levels in OECD countries: estimates for manufacturing and selected service sectors. Economics Department Working Papers, No. 169, Organisation for Economic Co-operation and Development, Paris.

Pilat, D (1996b) Competition, productivity and efficiency. *OECD Economic Studies*, **27**, 107–33.

PWT (2006) Penn World Tables. Available at http://pwt.econ.upenn.edu/php_site/pwt_index.php.

RBA (2007) Historical exchange rates. Reserve Bank of Australia. Available at www.rba.gov.au/Statistics/HistoricalExchangeRates/index.html.

Schreyer, P and Koechlin, F (2002) Purchasing power parities – measurement and uses. *OECD Statistics Brief*, March, No. 3.

Stapel, S (2002) The Eurostat construction price surveys: history, current methodology and new ways for the future. Paper presented at the International Conference on ICP, 11–13 March 2002, World Bank, Washington.

Stapel, S (2004) *Challenging the 'snapshot theory' of Purchasing Power Parities: Eurostat's revision of the PPP 1995 to 2000*. Available at www.ipeer.ca/papers/Stapel,June6,2004,_final_04_6_04.pdf.

Vermande, H and van Mulligen, P-H (1999) Construction costs in The Netherlands in an international context. *Construction Management and Economics*, **17**, 269–83.

Walsh, K and Sawhney, A (2002) *International comparison of cost for the construction sector: towards a conceptual model for Purchasing Power Parity*, Report submitted to the World Bank Group, June 2002.

Xiao, H and Proverbs, D (2002) The performance of contractors in Japan, the UK and the USA: a comparative evaluation of construction cost. *Construction Management and Economics*, **20**, 425–35.

THE WAY WE BEHAVE: PROPAGANDA AND ORGANIZATIONAL CITIZENSHIP BEHAVIOUR

Anita M M Liu[1] and Richard Fellows[2]

[1]*Dept. of Real Estate and Construction, University of Hong Kong, Pokfulam, Hong Kong*
[2] *Dept. of Real Estate and Construction, University of Hong Kong, Pokfulam, Hong Kong & School of the Built and Natural Environment, Glasgow Caledonian University, UK*

Today, firms are subject to a diversity of forces in the business environment that exert major impacts on performance objectives and targets. Many of the non-financial performance measures concern ethics of organizational behaviour, both inwards and outwards. Two particular behavioural considerations are organizational citizenship behaviour (OCB) and corporate social responsibility (CSR): OCB has an internal focus, whilst CSR looks outwards, primarily. The concepts of OCB of members of organizations, and organizations' behaviour in relation to perceived CSR is examined as components of more comprehensive citizenship behaviour. Construction projects are characterized as shifting, multi-goal coalitions based around a fluid power structure. That perception is examined from the perspective that the citizenship behaviours of participants may be manipulated through employment of propaganda to advance the ideology-driven agendas of certain (groups of) actors. The generic business environments within which project performances occur are, themselves, subject to propaganda-prone distortions. A particular difficulty is that the nature of propaganda renders it a covert activity with the consequence that the better it is carried out, the more difficult it is to detect and so, the paper, of necessity, draws attention to the distortions, engendered by propaganda, to which the behaviour of project participants, and those who seek to assess such behaviour, are subject.

Keywords: corporate social responsibility, organizational citizenship behaviour, propaganda.

INTRODUCTION

Today, firms are subject to diverse forces in the business environment that exert major impacts on performance objectives and targets. Construction projects are continuously and notoriously subject to diverse interests and pressures that seek to shape their processes and products. Such interests extend beyond the immediate project participants, corporate members and stakeholders to include many diverse individuals and groups – as epitomized in their being project coalitions (temporary multi organizations – TMOs) with changing memberships (e.g. Tavistock 1966; Egan 1998) and evolving goals dependent on ever-changing power structures rife with (potential) opportunism (Williamson and Maston 1999).

Financial forces focus on profitability, growth, cash flow (liquidity) and non-decreasing dividend streams. Whilst it may be argued that such financial measures constitute the primary performance imperatives for firms' survival, many of the non-financial performance measures constitute mechanisms for long term sustaining/enhancement of financial performance and concern ethics of organizational

[1] ammliu@hkucc.hku.hk

behaviour, both inwards and outwards. Two particular behavioural considerations are organizational citizenship behaviour (OCB), how individuals behave as organizational members, and corporate social responsibility (CSR), how the organization behaves as a responsible citizen of society. Both constructs are behavioural, concern ethics and, hence, are rooted in culture. Thus, an essential element in analysis of organizations is the context in which they operate, i.e. the nature of the society and the market including the members of the organization and its stakeholders.

Given that propaganda is “any association, systematic scheme, or concerted movement for the propagation of a particular doctrine or practice” (OED 2005), it influences the way people behave. The objective of this paper is to develop a conceptual model to examine propaganda in relation to citizenship behaviour of organizations – comprising OCB and CSR – within the context of construction.

CORPORATE SOCIAL RESPONSIBILITY (CSR)

Traditionally, CSR has a focus outward from the organization and concerns the actions of an organization towards the macro society. Macromotives – attributes that characterize individuals’ feelings and beliefs about others with whom exchanges occur – determine the potential for and operation of exchanges. The essential macromotives for relational contracts and social exchanges to be viable are trust, loyalty and commitment (Rousseau and Parks 1993).

Relations between organizations and society are “interwoven rather than being distinct entities” (Wood 1991), consequently, expectations of society impact on CSR. Social exchanges concern relationships involving future obligations that are unspecified (Blau 1964) and so generate expectation of returns in the future for contributions made. Social exchange contracts are based on long-term exchanges which are fair in the views of the parties, therefore, they do not require precise account-keeping but do require reciprocity of behaviour concerning the diffuse obligations involved (Graham and Organ 1993). Good faith and trust underpin the forms and timing of reciprocations and so, promote citizenship behaviour (Organ 1988) in the case of organizations in society.

Carroll (1979) contrasts ethical and philanthropic responsibilities by stating that the latter are what ‘should’ be done by the organization and adopts a model of CSR that has four component responsibilities: economic (profitability), legal (law-abiding), ethical and philanthropic (what society desires). The ethical responsibilities concern obligations beyond the legal requirements and involve doing what is considered to be right and fair – what society expects from a good (ethical) organization.

Over recent years, two sets of forces, privatization and globalization, are evident that countermand and modify citizenship. Privatization transfers the responsibilities for many social provisions (health care, education, pensions, etc.) (back) to individuals who then seek to obtain desired provisions (or effect insurance) through private means and organizations. Under privatization, rights are eroded and become wants, the satisfaction of which is subject to the operations of capitalist markets. Globalization reduces the importance and impact of territorial domains. Major governments and private organizations operate with increasing international influence, thereby reducing the sovereignty of, especially smaller/less economically powerful nation states. Important elements in the power gains of (private) organizations are lobbying of politicians and officers of governmental agencies, and contributions to funds of political parties, thereby distorting the operation of ‘enlightened self-interest’ (Smith 2000) and liberalism.

In a hypothetical perfectly ethical world, organizations would not require regulation; but, in practice, the statutory/legal controls (health and safety, town planning, environmental protection, etc.) act to secure minimum levels of ethical performance to protect society. In a less than perfect (‘real’) world, many businesses regard CSR as additional, discretionary activities that should be pursued only to the extent that ‘traditional’ (financial) measures of organizational performance are enhanced (Burke and Logsdon 1996), perhaps, especially, short term measures (Hutton 1996).

In delineating the boundaries of CSR, in terms of where relevant society lies, stakeholder theory asserts that an organization has responsibility to all persons (groups) affected (actually/potentially) by its actions – as in true professionalism. Further, relationships between organizational ethics and performance, and CSR and performance have been examined (e.g. McWilliams and Siegel 2000). Stevens (1994) discusses a variety of organizational motives for their use of codes of ethics: limiting legal liability, influencing employees’ behaviour and image building. Such codes represent documented statements of corporate values and norms and so, to be effective, must be communicated clearly. For many corporate statements, communication of meaning is notoriously problematic as the statements tend to be strategic and, hence, too vague for (immediate) operation – interpretation is necessary, which involves scope for flexibility.

The effects of propaganda are important to the study of CSR. Hence, it is worthwhile examining the effects of communication means and how propaganda impacts on people’s interpretations and judgements.

ORGANIZATIONAL CITIZENSHIP BEHAVIOUR (OCB)

Citizenship is rooted in relations between individuals and the (nation) state. Eriksen and Weigård (2000: 15) note that Aristotle (1992) considers citizenship to be the “right to participate in the public life of the state, which was more in the line of a duty and a responsibility to look after the interest of the community” – a citizen performs actions underpinned by a sense of duty of what is right and what is wrong.

Morals concern judgements of what behaviour is good/bad, right/wrong. Thus, values are central to the issue and context dependency must be addressed – a reflection of the cultural dimension of Universal-Particular (Trompenaars and Hampden–Turner 1997). Can any action, belief etc., be good or bad, right or wrong universally? That is not to dismiss objectivism but to acknowledge the pluralism of human existence. Hinman (1997) distinguishes morals as first order beliefs and practices about what is good and what is bad which guide behaviour, and ethics as second order reflective consideration of moral beliefs and practices. Rosenthal and Rosnow (1991: 231) note, “ethics refers to the system of moral values by which the rights and wrongs of behavior … are judged”. Snell (1995: 155) notes that moral ethos, which can be a strong force to encourage or constrain action, is, “the social climate predisposing members of an organization toward adopting and enacting some particular ethical standards and deflecting them away from others”.

Rokeach (1972) regards values as signifying enduring beliefs in particular ways of behaving or preferences for states in the future. That raises questions of (1) whose values are to be employed in determining the standards and related issues requiring people to exercise judgement in the business context, as well as (2) how do values impact on one's behaviour in the context of an organizational citizen?

For instance, construction project TMOs comprise many stakeholders who have diverse values, interests and, hence, operational objectives. While such pluralism may be helpful, it articulates the ethical question of whose values (should) apply. Are the values to be applied on a project the result of cognitive integration and agreement or due to evolving dominance of the (financially) most powerful?

Generally, OCB is behaviour in the execution of employment which is in excess of contracted/normal job performance and which is likely to contribute to long term success for the organization. Thus, OCB contributes to organizational effectiveness, and efficiency, but is not subject to the organization's formal rewarding structure and is discretionary by individual employees. Organ (1988: 4) defines OCB as "behavior that is discretionary, not directly or explicitly recognized by the formal reward system, and that in aggregate promotes the effective functioning of the organization…the behavior is not an enforceable requirement of the role or the job description…the behavior is a matter of personal choice".

CONCEPTUAL MODEL OF CORPORATE BEHAVIOUR

CSR guides corporate behaviour (B_{corp}) in an outward-orientation towards fulfilling the organization's obligations to society.

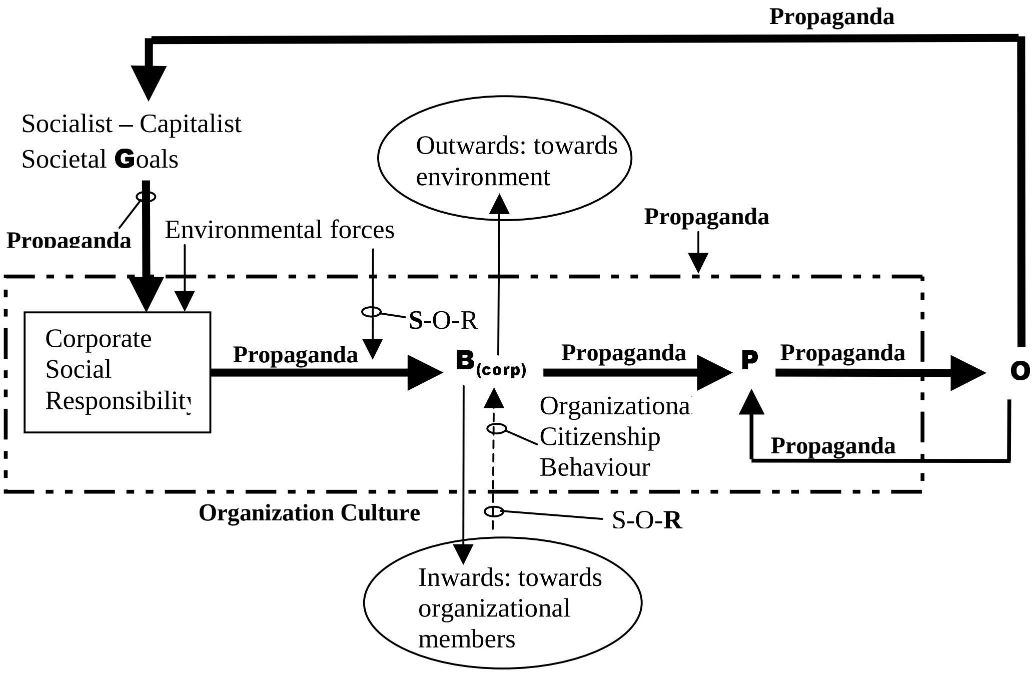


Figure 1: Influence of propaganda on behaviour (Key: S-O-R : stimulus – organism – response; $B_{(corp)}$: behaviour of the corporation; P: Performance; O: Outcome)

In the proposed model (Figure 1), CSR is envisaged as part of the response to the pressures of societal gaols according to the S-O-R (stimulus-organism-response) paradigm in organizational psychology. Environmental pressures (e.g. economic, legal, social etc.) act as stimuli on the organization and cause it to make a response.

Part of the response is to create a sense of CSR that may, finally, come to fruition in the form of a full response by bringing forth actions (or committing behaviours, B_{corp}) in fulfilling the societal goals.

Societal goals may vary in situational contexts of, say, socialist vs. capitalist economies. For instance, the organizations are expected to fulfil more extensive obligations and duties for the good of society and community in a socialist country. In China, previously state-owned enterprises (SoEs) were undertaking huge CSR (housing provision etc.). In present times, the SoEs are transformed to become non-state owned in the legal context but the business funding, control and operating mechanisms have undergone minimum changes in many large organizations. Those mechanisms were designed to fulfil governmental socialist goals. If societal goals remain unchanged, and minimal modifications are made to the business models (e.g. economic resource allocation, governance structure etc.), has CSR been reshaped? Take the case of housing provision where the Chinese government used to provide major input; in the immediate transition from a command economy, society may not be expecting less from the government and the government is not entirely releasing 'control' to the market.

The conceptual model in Figure 1 is explained further in terms of a behavioural approach to organizational analysis.

Goal – Behaviour – Performance – Outcome (GBPO)

A conceptual model of behaviour-performance-outcome (BPO) is proposed by Liu (1999) for construction procurement. The act is the basic unit of behaviour in the act-to-outcome process (Naylor *et al*. 1980) and has two defining dimensions, the amplitude (total commitment to an act as defined by the amount of individual time and effort allocated to the performance of that act) and the direction (the specific kind of activity being carried out). Evaluation of the outcome of an act is dependent upon two sets of contingencies (Naylor *et al*. 1980): (1) performance-to-evaluation contingencies and (2) evaluation-to-outcome contingencies. Thus, it is conceptualized that the behaviours (B), or acts, lead to performance (P) to produce an outcome (O) to be assessed. Goal-directed behaviours result from the organization responding to the environmental forces, i.e. the organization sets its goals (as in strategic planning) and adopts appropriate behaviours in pursuit of those goals.

The resultant behaviour of the organization (B_{corp}) has two interdependent components, inward towards its organizational members and outward towards the environment/society. The former constitutes how 'corporate' treats organizational members and, in turn, members make their responses by committing actions/behaviours which reflect OCB (e.g. Organ's (1988) OCB dimensions of sportsmanship, civic virtue, altruism, courtesy, and conscientiousness.) The latter constitutes a response from the organization to the environmental forces by committing actions/behaviours to fulfil CSR.

Dainty *et al*. (2005) assert that project affinity, emotional attachments to the project (objectives/purpose) outcome, enhances how people work, especially their OCB, thereby fostering performance. However, since the project organization is a shifting multi-goal coalition, stakeholders' (diverse) interests necessarily affect the direction and effort (amplitude and intensity) of behaviours.

Propaganda

The concept of propaganda relates to propagation – the widespreading – of ideas etc. to stimulate a pervasive and particular response. Propaganda is "The systematic propagation of information or ideas by an interested party, esp. in a tendentious way in order to encourage or instil a particular attitude or response. Also, the ideas, doctrines etc., disseminated thus; the vehicle of such propagation" (OED 2005). Thus, propagation relates to securing ends rather than the objective correctness/justice of the notions which are propagated. In the proposed model (Figure 1), propaganda plays a pervasive role in the operation of the GBPO cycle.

Propaganda involves widespread communication, usually of doctrinaire style and content, with the objective of advancing the interests of the perpetrators. A usual perspective on propaganda is an endeavour to effect change; alternatively, it could be employed to reinforce a status quo. Hence, propaganda is a tool employed by the organization to indoctrinate its members (see Figure 1) to enhance organizational culture; propaganda is also used by society to foster goal setting in shaping the organization's CSR, including endeavours to overcome resistance.

DISCUSSION

Organizations in Western countries use mission statements and, more overtly, advertising and promotional 'catch phrases' to help create a favourable image. Signs on construction sites, however, tend to be relatively factual in providing information about what is under construction and the identities of the major participants. In less market-developed societies, such as mainland China and other command economies, notices on construction projects are quite different in purpose and content. Slogans are paramount. The (recent) social tradition is that all policies and initiatives, including construction projects, are led by a slogan that serves to announce the great value/purpose of the project and so, serves to foster acceptance of the project, motivate workers on it and promote it amongst potential users. Such slogans continue the central place of slogan-based propaganda, which has served government of such societies for some time to help effect and direct the focus of information dispatch; however, increasing access to global media and other propaganda techniques is rendering the displaying of signs and slogans of less effect – television advertising and internet access, despite 'firewalls', reach huge audiences rapidly and to greater effect.

Common propaganda techniques involve language distortions of various types – including the use of generalized statements that leave the recipient to 'fill-in' the picture by envisaging specifics. Many other forms exist to inculcate beliefs and consequent actions (if only of non-resistance), including implications of general beliefs/knowledge, alienation of non-conformists, and threats of many forms.

The construction industry is towards the forefront of several changes/initiatives – e.g., environmental impact reduction and privatization. In UK, the majority of projects for the, now much reduced, public sector are carried out under formal private finance initiative (PFI) arrangements – a form of concession contracting, design-build-finance-operate (DBFO). PFI constitutes a particular form of public private partnership (PPP). At face value, partnership sounds, 'just what the industry needs', involving teamwork, cooperation, collaboration, dispute avoidance, etc., but, partnership is not partnering although, in the context of PPP, it is commonly portrayed as such.

In the realm of propaganda, partnering is, essentially, a trust-based, collaborative, and enduring relationship between construction project participants. The objectives of partnering (previously teamwork) are to enhance returns to the participants through improving project management performance – i.e., enhancing efficiency of supply. If partnering has such extensive benefits as claimed by its advocates, it is amazing that it remains unusual in practice and operates only partially in most instances. That, of course, could be an issue of differing definitions or evidencing that it is inappropriate for construction. An acid test could be whether its advocates practice full partnering themselves. According to Green (1999) that is not the case and further, powerful anecdotal evidence supports Green's findings. Green notes that major clients who are leading advocates of partnering in construction conduct far more 'traditional', self-interested practices in their core businesses and so accord with Cox's (1999) value appropriation assertion. How often are those who realize the project on the construction site not told that it is a partnering project (because if they were told they would not act to maximize and pursue 'our contractual rights and opportunities')? Gruneberg and Hughes (2006) report that construction consortia are formed to win contracts – as marketing devices to give the impression of teamworking but, in reality, leaving much fragmentation – and, often, are little more than financial vehicles.

Ezulike *et al*. (1997) examine a variety of issues for constructors during the early years of PFI in UK. They report the commonality of constructors endeavouring to extricate themselves from PFI project arrangements following completion of construction to assist their moving on to further projects but retaining their traditional (financial) structure and ways of operating largely intact while building an experiential portfolio of PFI projects to aid marketing and securing further PFI work.

Propaganda, especially if viewed from a functional/intentions perspective, may occur in three main forms – positive communication, negative communication, and withholding communication; i.e. two active and one passive form. Positive communication exhibits bias of potential advantages – as much literature advocating partnering, PPP, PFI, etc., in construction. Negative communications are biased towards disadvantages/problems – as in discussions of constant use of contractors/subcontractors without competitive tendering. Withholding communication can relate to positive or negative issues – as in product suppliers failing to inform consumers of faults in the product and, thereby, encouraging the consumers to behave according to information known to be false (a failure of CSR also).

Professional practitioners in construction now operate largely under normal business competition and so, are subject to both the business performance requirements and those of professionalism (ethics). That is occurring at a time when there are pressures on businesses to be more diverse in responding to interests of their various stakeholders and to be more (widely) ethical in their behaviour (e.g. CSR; environmental impact reduction). However, such changes can be viewed as responses (also) to propaganda – by advocates of market competition, consumer groups and environmentalists – the objectives of some of which are more morally-determined than others. Propaganda is an ethical issue and, as such, has a moral and cultural foundation. Determination of what constitutes propaganda and any limits for acceptability are value-judgements.

Within the context of business process reengineering, Green (1998) notes the use of fear to generate attention and, then, to make recipients of the communications more susceptible to the contents – the changes sought by the perpetrators of the messages. Such fear is generated through assertions that deficient performance will ensue unless action is taken to follow the content of the messages; as such, much content of the messages can be left as implications through use of the prevailing socio-economic system and its performance imperatives as perceived by the audience (managers – as the organizational decision makers). Clearly, the endeavour is to persuade those decision makers to change the operating objectives and processes to yield greater (expected) benefits (value – see, e.g., Cox 1999) for the propagandists. Cox's (1999) perspective is reinforced by Hutton (1996) who notes the common performance imperative of companies to declare non-decreasing dividend streams due to the expressed criteria of fund managers – as the primary active investors on the global stock market. Clearly, the 'own value' (financial performance) criterion, and not CSR, is dominant.

CONCLUSIONS

The constructs of OCB and CSR are, *prima facie*, positive but the determination of their presence and extent is dependent on societal goals and norms. Their apparent presence may be occasioned through propaganda mechanisms, fear and other negative, even cheating, means. Pressures to perform apparent OCB (such as working extended hours) may be enhanced by the organizational climate or occasioned by rumour stories to engender fear of losing the job due to non compliance in order that the organization secures greater work output at zero (financial) cost, e.g. the construction industry in Hong Kong is known for its long working hours.

Construction is a technical medium of business activity. Its members are subject to self-interested pressures for outcomes from many diverse stakeholders. Stakeholder values, as performance requirements are expressed forcefully from individual perspectives. Thus, ethics, technical and business behaviours may conflict leading to distortions of apparent OCB and CSR behaviours. In many contexts, propaganda is rife in construction, often as a form of generic opportunism.

Whilst the 'goalposts' for extra-statutory CSR are advancing (environmental protection, health and safety, eco-labelling, etc.), often, apparent CSR actions are undertaken voluntarily to gain a foothold in a market or increase market share, to provide some immunity from potential liabilities (as in quality assurance and environmental protection certification) or as a taxation manoeuvre which also enhances the image of the organizations (e.g. charity donations).

If CSR behaviour, analogous to OCB, is regarded as behaviour in excess of norms and of legal requirements, then it comprises only ethical and discretionary categories relating to social issues. The philosophy of social responsiveness categories are less clear in their applicability for CSR as reaction and defence are usually in response to external forces – which may apply to accommodation also – leaving the only optional category to be proaction. (Even proactive measures may be taken in anticipation of future external forces – legislation etc.)

ACKNOWLEDGEMENT

This paper is partially funded by the grant from RGC, CERG HKU 7122/03E.

REFERENCES

Aristotle (1992) *Eudemian Ethics*. Trans. H Rackham. Cambridge, MA: Harvard University Press.

Blau, P (1964) *Exchange and power in social life*. New York: Wiley.

Burke, L and Logsdon, JM (1996) How corporate social responsibility pays off. *Long Range Planning*, **29**(4), 495–502.

Carroll, A B (1979) A three dimensional model of corporate social performance. *Academy of Management Review*, **4**(4), 497–505.

Cox, A (1999) Power, Value and Supply Chain Management. *Supply Chain Management*, **4**(4), 167–75.

Dainty, A R J, Bryman, A, Price, A D F, Greasley, K, Soetanto, R and King, N (2005) Project affinity: the role of emotional attachments in construction projects. *Construction Management and Economics*, **23**(3), 241–4.

Egan, Sir J (1998) *Rethinking Construction, The Report of the Construction Task Force*. London: DETR.

Eriksen, E and Weigård, J (2000) The End of Citizenship? *In:* C McKinnon and I Hampsher-Monk (Eds.) *The Demands of Citizenship*. London: Continuum.

Ezulike, E I, Perry, J and Hawash, K (1997) The barriers to entry into the PFI market. *Engineering, Construction and Architectural Management*, **4**(3), 179–93.

Graham, J W and Organ, D W (1993) Commitment and the covenantal organization. *Journal of Managerial Issues*, **5**, 483–502.

Green, S D (1998) The technocratic totalitarianism of construction process improvement: a critical perspective. *Engineering, Construction and Architectural Management*, **5**(4), 376–86.

Green, S D (1999) Partnering: the propaganda of corporatism? *Journal of Construction Procurement*, **5**(2), 177–86.

Gruneberg, S and Hughes, W (2006) Understanding Construction Consortia: theory, practice and opinions. *RICS Research Paper Series*, **6**(1), March. London: Royal Institution of Chartered Surveyors.

Hinman, L M (1997) *Ethics: A Pluralistic Approach to Moral Theory*. Orlando, FL: Harcourt Brace Jovanovich.

Hutton, W (1996) *The State We're In*. 2ed. London: Vintage.

McWilliams, A and Siegel, D (2000) Corporate social responsibility and financial performance: correlation or misspecification? *Strategic Management Journal*, **21**, 603–9.

Organ, D W (1988) *Organizational citizenship behavior: The good soldier syndrome*. Lexington MA: Lexington Books.

Oxford English Dictionary (2005) Available online: http://dictionary.oed.com/cgi/entry_main; (accessed 7 December 2005).

Rokeach, M (1972) *Beliefs, attitudes and values: a theory of organization and change*. San Francisco: Jossey Bass.

Rosenthal, R and Rosnow, R L (1991) *Essentials of Behavioral Research: methods and data analysis*. 2ed. Boston, MA: McGraw-Hill.

Rousseau, D M and Parks, J (1993) The contracts of individuals and organizations. *In:* L L Cummings and B M Staw (Eds.) *Research in organizational behaviour, Vol. 15*. Greenwich CT: JAI Press.

Smith, A (2000) *An inquiry into the nature and causes of the wealth of nations*. New York: Modern Library.

Snell, R (1995) Psychic Prisoners? Managers facing Ethical Dilemmas: cases from Hong Kong. *In:* S Stewart and G Donleavy (Eds.) *Whose Business Values*. Hong Kong: Hong Kong University Press.

Stevens, B (1994) An analysis of corporate ethical code studies: where do we go from here? *Journal of Business Ethics*, **13**, 63–9.

Tavistock Institute of Human Relations (1966) *Interdependence and Uncertainty: a study of the building industry*. London: Tavistock Publications.

Trompenaars, F and Hampden-Turner, C (1997) *Riding the Waves of Culture: understanding cultural diversity in business*. 2Ed. London: Nicholas Brealey.

Williamson, OE and Maston, SE (Eds.) (1999) *The Economics of Transaction Costs*. Cheltenham: Edward Elgar.

Wood, D J (1991) Corporate performance revisited. *Academy of Management Review*, **16**(4), 691–718.

A COMPARATIVE STUDY OF GROUP INTERACTION

Christopher A. Gorse[1]

School of the Built Environment, Leeds Metropolitan University, Queen Square Court, The Northern Terrace, Civic Quarter, Leeds LS1 3HE, UK

Group interaction is a fundamental aspect of multidisciplinary construction projects, yet only a few studies of construction groups engaged in a 'bona fide' meeting exist. In an attempt to fill this gap, the Bales Interaction Process Analysis (IPA) method was used to observe and classify interaction from 36 management and design team meetings. By aggregating the data together a single profile of group interaction was produced. The profile represents the first attempt to model the communication behaviour of a management and design team meeting. Comparisons with existing IPA models show that there are similarities and differences between construction and non-construction related groups. Interaction features associated with task and socio-emotional behaviour are highlighted and discussed. In construction teams, the level of socio-emotional communication was much lower than the task-based interaction. Interestingly, while many suggest that construction is surrounded by adversarial behaviour, the level of conflict and disagreement found was lower than that found in many other contexts.

Keywords: communication, group work, meetings.

BACKGROUND

While teamwork and group interaction are fundamentally embedded in construction management few researchers have investigated this topic. Furthermore, although much is written on communication little of it is supported by research (Emmitt and Gorse 2003; Dainty *et al.* 2006). As a starting point, a detailed investigation into the communication behaviour of construction groups compared to other groups should help establish a contextual model of communication. Issues that are of specific concern and worthy of further investigation include aspects of interaction that relate to the management of relationships and tasks.

Selection of an appropriate research method

For nearly a century scholars have suggested that group communication can be viewed as task or emotionally oriented. Researchers today still recognize these two factors of group communication. And, although debated, the literature's prevailing ethos treats this distinction as an uneasy alliance, but accepts it as a key characteristic of groups (McLeod and Kettner-Polley 2004). These two dimensions are considered to be essential components in the management of interpersonal relationships and the accomplishment of tasks. For the group to exist and develop the members engage in relational communication (socio-emotional) and, to achieve outcomes, groups move through various phases of task-based discussion (Bales 1970).

[1] C.Gorse@leedsmet.ac.uk

Although there are a number of research methods used for recording group communication the Bales Interaction Process Analysis method provides a robust method with a clear focus on the socio-emotional and task-based components.

The Bales IPA method of observing, recording and investigating communication is well established. Having stood the tests of time it has been used in research methods that have produced seminal works such as Tuckman's (1965) model of group development and Belbin's (1981, 1993) work on team roles. Recent studies have used the method to investigate interaction in self-managed work teams (Armstrong and Priola 2001) and virtual environments (Chou 2002; Fahy 2006). Even with the advent of new technologies, different ways of working and new processes have not reduced the usefulness of this research method. Bales IPA is versatile and robust and although other methods claim to offer additional features, the longevity of use has resulted in a considerable body of information, which has steadily developed understanding of group interaction in various contexts.

The IPA observation method has seen a recent decline in use with researchers opting to use self-perceptions and interpersonal ratings from within the group. Two reasons for this shift is that direct observation is costly and time consuming and interpersonal ratings allows for all members to provide their perceptions of each other member, which yields rich information about biases and motivated perceptions (McLeod and Kettner-Polley 2004). What is lost with interpersonal ratings is the considerable detailed information and fine grain analysis of group behaviour and development that is only possible with direct observation (McLeod and Kettner-Polley 2004). Some research projects which have used interpersonal ratings to delve into members' beliefs have also supported their analysis with the Bales IPA direct observation. For example, Armstrong and Priola (2001), and Priola *et al.* (2004) made use of interpersonal ratings, the Bales IPA and discourse analysis to investigate cognitive styles and group work although their work is conducted in staged environments. Unfortunately where participants are requested to voluntarily take part in 'real world' research projects that require them to undertake additional tasks response rates to research demands suffer. It is commonly accepted that a low response rate (30–40%) to questionnaires is normal. Few researchers question what differences might be occurring between those who participated and those who did not. However, when attempting to model the interaction behaviour of a group it is necessary that all members of the group agree to participate.

Although direct observation is time consuming for the researcher, analyst and observer it places no resource implications on those being observed; indeed, it is desirable for those being observed to carry on as normal – not doing anything different. Interestingly the Bales SYMLOG system, which is based on interpersonal ratings, can take the participants three to four hours to understand and complete (Bales 1980). Emmitt and Gorse (2007) experienced considerable difficulties when attempting to obtain valid and consistent interpersonal ratings and reflections from professionals. Work demands and lack of interest meant that feedback sheets required from the professionals were given a low priority and the contributions and content varied with a significant number of professionals not responding with any meaningful content. Direct observation using the Bales IPA method, which places minimal demands on the participants, is an effective way of collecting interaction data from professional groups and is still as useful as it was in the 1950s when it was first introduced.

IPA and construction research

The Bales IPA has been used extensively in many fields, although rarely used in construction; exceptions include work by Gameson (1992), Gorse (2002, 2007), Bellamy *et al.* (2005) and Wallace (1987). However, Wallace used a bespoke methodology with components taken from the Bales IPA. Unfortunately the bespoke method, with many more categories than the IPA, unbalances the categorization process, meaning that even in the categories that are exactly the same, they may be apportioned differently from the IPA system. For example, where once an IPA category would have taken preference in coding a particular act, a communication category from another method may take preference. Thus, the original Bales communication description may receive reduced use because of the presence of another description. The Bales system can be used alongside other methods, but once mixed in a bespoke method the results produced are difficult to compare.

Examples of existing research that has used the IPA method to examine group interaction in other fields includes Bales' (1950, 1970) profiles of children, married couples and academic groups; Cline's (1994) study of disagreement and agreement; Landsberger's (1955) records of mediation meetings; Bell's (2001) observations of multidiscipline child protection teams and Fahy's (2006) comparison of face to face and online groups. Bellamy *et al.* (2005) conducted a study similar to that of Fahy's work, in construction, and looked at the difference between co-located and virtual design teams using the Bales IPA. Interaction studies from various contexts will provide data showing which environments produce similar interaction to construction. Where similarities are noted, the findings provided from the earlier research will also highlight issues that could impact on group interaction in construction projects.

RESEARCH METHOD

The data were collected from management and design team meetings. The meetings observed were collected from 10 different contracts with project values ranging from of 3 million to 8 million pounds sterling. A minimum of three meetings were observed for each case study. Observations were recorded using the Bales Interaction Analysis Process (IPA) technique, which identifies the communicator and the recipient (target of communication). The Bales method also permits classification of the statement into either one of six 'task-related categories' or six 'socio-emotional categories' (Table 1). The observer recorded the data using a prepared check-sheet with tick-boxes enabling the identification of the person speaking, recipient, and the interaction category that classified the statement used. The observer sat at the meeting table, and the participants were aware that the researcher was observing. The observer took no active role in the meeting. A brief qualitative note was made of the issue being discussed.

Table 1: Bales 12 interaction categories (adapted from Bales 1950: 9)

ID	Bales' categories and description	Group
1	Shows solidarity – show support, raises others' status, gives help, encourages others, reinforces (rewards) contribution, greets others in a friendly manner, uses positive social gesture, shows element of kindness.	Social-emotional area Positive reactions. Behaviours and gestures used to engage others in positive manner, can be used to encourage commitment, help build and strengthen relationships.
2	Shows tension release – jokes (supportively), laughs, shows satisfaction, relieves or attempts to remove tension, offers way out of problem, expresses enthusiasm, enjoyment, satisfaction.	

3	Agrees – shows passive acceptance, acknowledges others, shows understanding, complies, cooperates with others, expresses interest and comprehension.	
4	Gives suggestion – makes suggestion, provides direction or resolution, implying autonomy for others, attempts to control direction or decision. Makes clear and firm statement. Shows the way forward.	Task area: neutral Input and attempted answers. Acts used to give, exchange and develop information, understanding and control. Provides information and clues about context, topic, goal and direction.
5	Gives opinion – offers opinion, evaluation, analysis, express a feeling or wish. Seeks to analyses, explore, evaluate or enquire. Provides insight and reasoning. Offers view, without imposing direction on others.	
6	Gives orientation – provides background, further information, repeats, clarifies or confirms. Brings relevant matters of fact into the forum, acts that assist group focus on the context rather than the direction.	
7	Asks for orientation – asks for further information, repetition or confirmation. Draws out issues, facts and background information. Acts used to request relevant information and understand the topic and context.	Task area: neutral Questions and requests. Information finding and question asking. Acts used to request, seek, draw, search, withdraw, analyse and explore information. Also includes requests for direction
8	Asks for opinion – asks others for their opinion, evaluation, analysis or view. Requests that others express how they feel or state their preferences. Acts used to request and explore reasoning.	
9	Asks for suggestion – asks for suggestion, direction, possible ways of action. Requests for firm contribution, solution or closure to problem. Asks another member to take on autonomy of others.	
10	Disagrees – shows disagreement (without any anger or tension), passive rejection, expresses position to withhold help, does not support view or opinion, openly fails to concur with view, rejects a point or suggestion.	Social-emotional area Negative reactions. Include non-conformative acts that show little emotion to outward aggression. Behaviours used to disagree, reject information, question commitment and threaten relationships.
11	Shows tension – shows concern, apprehension, dissatisfaction or frustration. Persons interacting are tense, on edge. Disagreement supported by negative emotion. Acts that express sarcasm or are condemning.	
12	Shows antagonism – acts used to deflates others' status, asserts self on others. Openly suppresses another member, purposely blocks another or makes a verbal attack, expressions of aggression and anger.	

RESULTS

The line graph (Figure 1) representing the management and design team meetings illustrates the trend of group interaction found in the management and design team meetings. This provides an example of the group interaction norms operating within the meeting. The results show that the groups use a high amount of task-based interaction (categories 4–9) and a relatively low level of socio-emotional communication. Socio-emotional interaction represents the interaction used to build, develop and maintain relationships and that used to engage in conflict and threaten relationships. Socio-emotional interaction is often termed relationship communication, the acts help to engage, strengthen, threaten and withdraw from relationships.

Examining the results in more detail: the groups' use of giving task-based interaction (categories 4–6) is consistently higher than that of requesting task-based interaction (categories 7–9). The positive socio-emotional interaction (categories 1–3) is also consistently higher than the negative socio-emotional communication (categories 10–12). The level of positive and negative emotional interaction is low. Although the construction sector is often described as an emotional and volatile environment, this is not evident from the data. Although it cannot be said that this model is representative of all construction site meetings, it was drawn from a sample of 36 meetings from which 15 077 communication acts were observed. On this basis, the model shown provides the most comprehensive picture of group communication during construction meetings to date.

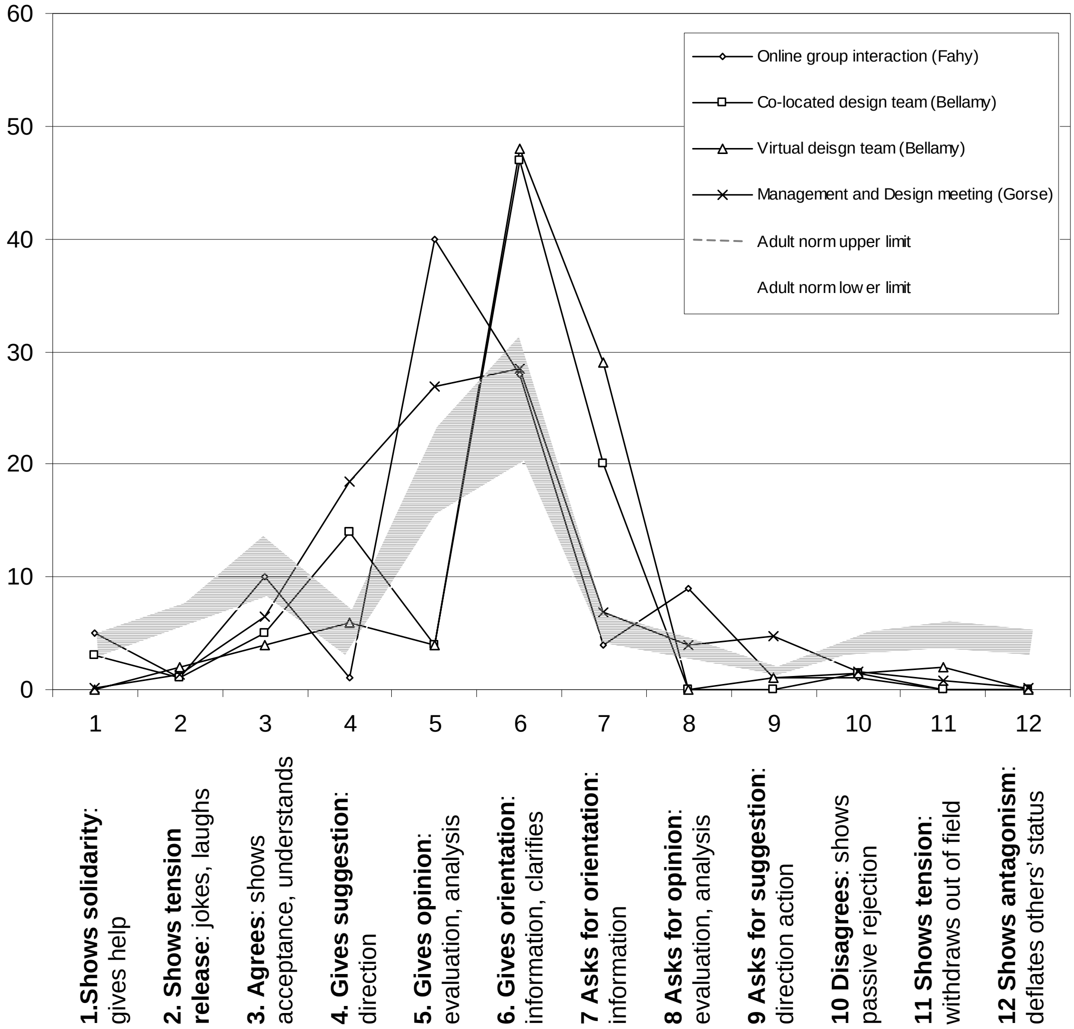


Figure 1: Graph showing Bales original study of Adult norms and studies of construction based interaction

DISCUSSION

When comparing the line graph (Figure 1) to previous studies the results shows considerable difference between the construction-based studies and the upper and lower limits of interaction norms as depicted by Bales (1970). The shaded area of the graph represents Bales' normal ranges of interaction. All of the construction-based studies show very low use of the socio-emotional acts, especially when compared to Bales normal range. Fahy's (2006) study, which is based on students' online interaction, is the only graph that drifts into Bales normal zone. Results from previous studies that have investigated construction professionals' interaction, such as Wallace (1987) and Gameson (1992), have also found low levels of emotional expression. Much of Bales' work that was used to produce the normal range was based on student, counselling and social groups. The few studies that have investigated work groups show much lower uses of socio-emotional communication than that found in other contexts (Wallace 1987; Gameson 1992; Bell 2001; Bellamy *et al.* 2005). Studies by Bales (1970) found that groups which used a low amount of socio-emotional interaction were often in the early stages of group development.

As groups develop and become more familiar with each other their behaviour changes. Individuals within the group initially use task-based communication, tentatively gathering information on the other group members' personal behaviours, beliefs and attitudes before using socio-emotional interaction. Before openly engaging and committing into a relationship group members need to understand other members' motives and how they react to different messages. As each member engages in interaction and discussions continue a social interaction structure develops (Bales 1970).

Socio-emotional interaction supports the development of interpersonal relationships. By agreeing and disagreeing with issues interpersonal bonds and commitments can be strengthened and reduced. As the socio-emotional structure develops members become familiar with other members' communication behaviour and the level of socio-emotional interaction increases. Groups that reach the later stages of group development show an increased use of socio-emotional communication (Heinicke and Bales 1953; Bales 1970). Developed groups are said to have established their behaviour norms with individual members being more confident to express socio-emotional acts in order to manage relationships and work through the group tasks.

Group communication using Bales IPA

There are certain characteristics that are said to be associated with specific types of groups. For example, the behaviour juveniles have been found to be unstructured, lacking control and characterized by outbursts of emotion. Groups of children offer an example of what has been described as uninhibited and uncontrolled behaviour (Bales 1970; Socha and Socha 1994). As people mature their behaviour becomes more restrained (Socha and Socha 1994). Clearly the behaviour of the work groups, including that of the management and design meetings, is not emotionally expressive. Indeed much of the discussion is task-based as members attempt to express, understand and solve problems. In adult groups, information and suggestions are often supported by explanation; generally, communication in adult groups is structured, controlled and restrained (Bales 1950; 1970). Adults do not normally express high levels of extreme emotional behaviour. While the behaviour of construction professionals may be different from that of other groups, and not within the Bales normal range for adult groups, it does not resemble the behaviour of juveniles.

The few studies that have looked at work groups (Landsberger 1955; Gameson 1992; Bell 2001) provide initial evidence that the working and commercial environment reduces emotional communication to a lower level compared with other studies. Studies of online communication have found very low levels of socio-emotional communication (Bellamy *et al.* 2005) and Fahy (2006) noted a complete absence of negative socio-emotional interaction during computer-mediated discussion. However, these initial results should be treated with care. Criminal reports and general news shows that emails, text messages, blogs, photographs and identity impersonations can be emotionally manipulative (Channel 4 2006). Digital communication and emotional content is an area that requires further research. Clearly, the communication medium and environment has an effect on the nature and impact of communication.

The management and design team meetings shown in Figure 1 and the other work-based studies indicate that task-based communication consumes most of the meetings' time. Although many of the work-based issues discussed in the meetings necessitate the exchange of ideas, information and questions, and, to explore issues in depth, the use of questions and requests for suggestions are needed, the socio-emotional interaction plays an important part in the process. At its most basic level socio-emotional interaction includes agreeing and disagreeing; such acts are obviously essential in the discussion of problems. Socio-emotional acts include negative emotional statements and acts that are antagonistic or even aggressive; these acts can be used to weaken and threaten the relationship. However, all negative socio-emotional acts, including basic criticism and disagreeing can threaten the strength of a relationship. Positive socio-emotional acts such as agreeing, showing support and being friendly help to build and stabilize relationships (Bales 1970). In order to successfully discuss problems group members need the skills to enquire, analyse, disagree and show support. If issues are not discussed properly and people do not have the skills to show concern and disagree then problems could develop in the future. If a balance between positive and negative socio-emotional exchanges is not maintained the project relationships could be threatened.

In the meetings observed the exchange of socio-emotional interaction, although responsible for only a small proportion of the total interaction, resulted in a notable change in the group dynamic. Where negative emotional exchanges occurred the group became very attentive and focused. If arguments emerged some members appeared anxious. When positive emotion was used the mood of the meeting became more upbeat and relaxed. Even though socio-emotional interaction in construction groups is minimal it has an important role to play in the management of discussions. Further research is necessary to uncover how socio-emotional interaction is being used. By comparison with other studies it should be possible to establish an understanding of the effects of various communication acts. Knowing how we use communication and what effects the messages used have on others should be a basic part of the construction managers' training, yet such information is not widely available.

CONCLUSION

This study provides an overview of group interaction within management and design team meetings on construction sites. The results show an interaction pattern that has greater association with other work-based environments than it does with earlier studies of social situations. Earlier studies of interaction norms are different from those found in the more recent studies of work groups; a new set of interaction norms for *bona fide* work groups should be established. Further investigation is also required into the area of socio-emotional interaction and its link with project relationships. The use of negative and positive socio-emotional interaction within the site meetings was low. While this is inconsistent with reports that suggest that adversarial behaviour in the construction industry is endemic, failure to engage in socio-emotional interaction and resolve problems as they occur could lead to latent tension that threatens relationships. Socio-emotional interaction is directly tied to the resolution of task-based problems that require multiple parties. Parties must manage the relationship and tasks. Problems should be properly and rigorously discussed. Such discussions will result in stress that needs to be managed so that relationships are sustained. Clearly, such issues are fundamental to the construction industry and further research is necessary.

REFERENCES

Armstrong, S J and Priola, V (2001) Individual differences in cognitive style and their effects on task and social orientations of self-managed work teams. *Small Group Research*, **32**(3), 283–312.

Bales, R F (1950) *Interaction process analysis: a method for the study of small groups*. Cambridge, MA: Addison-Wesley Press.

Bales, R F (1953) The equilibrium problem in small groups. *In*: T Parsons, R F Bales and E A Snils (Eds.) *Working papers in the theory of action*. New York: Free Press.

Bales, R F (1970) *Personality and interpersonal behaviour*. New York: Holt, Rinehart and Winston.

Bales, R F (1980) *SYMLOG case study kit: with instructions for a group self study*. New York: The Free Press.

Belbin, R M (1981) *Management teams: why they succeed or fail.* London: Heinemann.

Belbin, R M (1993) *Team roles at work*. London: Butterworth-Heinemann.

Belbin, R M (2000) *Beyond the team*. London: Butterworth-Heinemann.

Bell, L (2001) Patterns of interaction in multidisciplinary child protection teams in New Jersey. *Child Abuse and Neglect*, **25**, 65–80.

Bellamy, T, Williams, A, Sher, W, Sherratt, S and Gameson, R (2005) Design communication: issues confronting both co-located and virtual teams. *In*: F Khosrowshahi (Ed.) *Proceedings of the 21st Conference of the Association of Researchers in Construction Management*, 7–9 September 2005, SOAS, London, 353–61.

Building Industry Communications (1966) *Interdependency and uncertainty: a study of the building industry*. London: Tavistock.

Channel 4 (2006) Text bullying on the increase. *MORE 4 News Forum*, 15 November, available at www.channel4.com/more4/news/news-opinion-feature.jsp?id=451.

Chou, C C (2001) *Student interaction in a collaborative environment: a model of learner-centred computer-mediated interaction*, Unpublished Dissertation, University of Hawaii at Manoa, Honolulu.

Chou, C C (2002) A comparative content analysis of student interaction in synchronous and asynchronous learning networks. *In*: *Proceedings of the 35th Hawaii International Conference on System Sciences*, available at www.hicss.hawaii.edu.

Cline, R J W (1994) Groupthink and the Watergate cover-up: the illusion of unanimity. *In*: L R Frey (Ed.) *Group communication in context: studies of natural groups*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Dainty, A, Moore, D and Murray, M (2006) *Communication in construction: theory and practice*. London: Taylor and Francis.

Emmitt, S and Gorse, C A (2003) *Construction communication*. Oxford: Blackwell Publishing.

Emmitt, S and Gorse, C A (2007) *Communication in construction teams*. Oxford: Spon Research, Taylor & Francis.

Fahy, P J (2006) Online and face-to-face group interaction processes compared using Bales' interaction process analysis (IPA). *European Journal of Open, Distance and E-Learning* (2006/i), available at www.eurodl.org.

Gameson, R N (1992) *An investigation into the interaction between potential building clients and construction professionals*, PhD Thesis, University of Reading.

Gorse, C A (2002) *Effective interpersonal communication and group interaction during construction management and design team meetings*, PhD Thesis, University of Leicester.

Gorse, C A and Emmitt, S (2003) Investigating interpersonal communication during construction progress meetings: challenges and opportunities. *Engineering, Construction and Architectural Management*, **10**(4), 234–44.

Higgin, G and Jessop, N (1965*) Communication in the building industry*. London: Tavistock Publications.

Kreiner, K (1976) *The site organisation: a study of social relationships on construction sites*, PhD Thesis, Technical University of Denmark, Denmark.

Landsberger, H (1955) Interaction process analysis of professional behaviour: a study of labour mediators in 12 labour-management disputes. *American Sociological Review*, **20**, 566–75.

Loosemore, M (1996) *Crisis management in building projects: a longitudinal investigation of communication behaviour and patterns within a grounded framework*, PhD Thesis, University of Reading.

Loosemore, M, Nguyen, B T and Denis, N (2000) An investigation into the merits of encouraging conflict in the construction industry. *Construction Management and Economics*, **18**, 447–56.

McLeod, P L and Kettner-Polley, R B (2004) Contributions of psychodynamic theories to understanding small groups. *Small Group Research*, **35**(3), 333–61.

Otter, den A F H J (2005) *Design team communication using a project website*, PhD Thesis, Bouwstenen 98, Technische Universiteit Eindhoven, NL.

Priola, V, Smith, J L and Armstrong, S J (2004) Group work and cognitive style: a discursive investigation. *Small Group Research*, **35**(5), 565–95.

Socha, T J and Socha, D M (1994) Children's task-group communication: did we learn it all in kindergarten? *In*: L R Frey (Ed.) *Group communication in context: studies of natural groups*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Sperber, D and Wilson, D (1986) *Relevance communication and cognition*. Oxford: Blackwell.

Tuckman, B W (1965) Developmental sequence in small groups. *Psychological Bulletin*, **63**, 384–99. Reprinted in *Group Facilitation: A Research and Applications Journal*, **3**, Spring 2001, available at http://dennislearningcenter.osu.edu/references/GROUP%20DEV%20ARTICLE.doc (accessed 14 January 2005).

Wallace, W A (1987) *The influence of design team communication content upon the architectural decision making process in the pre-contract design stages*, PhD Thesis, Heriot-Watt University.

DEFECTIVE WORKMANSHIP – ALIVE AND WELL

Wilson Barnes[1]

School of ACC, Southern Polytechnnic State University, 1100 South Marietta Parkway, Marietta Georgie 30060, USA

This paper draws from a larger study that investigates defective workmanship through an interpretive approach generated by methodical analysis of construction cases drawn from English jurisprudence. That process serves to highlight the primary causal factors as well as secondary (sometimes proximate) causes of defective workmanship, and enables identification of repetitive characteristics or indices. Through ordered aggregation of these characteristics from readily available case histories, relationships are identified leading to a fuller understanding of the cause–effect linkage and of the dire consequences frequently realized. While the broader study included a similar analysis of data and interpretation for appropriate construction cases from American jurisprudence in the state of Florida, this paper discusses the resultant identification of architectonic location, conduct causal factors, and legal theory involved in the jurisdiction of England/Wales. Conduct causal factor identification was considered fundamental to classification of defective workmanship causes and its genesis is discussed more fully herein to facilitate understanding of the overall study structure. Derived knowledge of the resultant statistically grounded conduct causal factors will hopefully lead to better contractor performance and profit. The basic study examined cases reported from 1970 to 1996. This paper will present that information with frequent references to the identified data of interest and a brief discussion of updates to 2005. Despite a varying prevalence of legal favoured interest over the years, defective workmanship remains a persistent underlying reason for dissatisfaction of the construction product customer.

Keywords: building defects, construction law, culture, defective workmanship.

BACKGROUND

The construction processes with respective provisions and players come together in a complex coordinated manner. That orchestration is filled with ample opportunity for omission, discontinuity, conflict and dispute.

It can be argued that the construction delivery system is a network of interacting forces that define process. Two of the most important forces in the process are the contract, with its many variant conventions and regulatory control, with its numerous levels of coverage and enforcement. The contract and regulatory control (control by the public regulator) are fundamental to establishment and pursuit of relationships, responsibilities, duties and rewards. These forces, crucial to the operational climate, are ripe with potential for misinterpretation, bad performance, misfeasance and abuse.

As with any process, no matter how rigid or loose-knitted it may be defined, that of construction is subject to exploitation by those who seek out holes in the net or slack

[1] wbarnes@spsu.edu

in the system. This was discussed extensively by Clegg, especially with regard to the potentials mentioned above (1992: 128–44). Cheetham noted, ‘It is the complexity of contractual obligations and the large number of co-operating organizations that has given rise to an extremely litigious industry’ (1993: 86–98). Despite a generally high order of professionalism among practitioners and manifest professions of goodwill, there are those whose conduct is driven by opportunism and the easy way out. Although most people want to avoid legal entanglement, ‘the nature of the construction process seems inevitably to lead parties frequently to the brink of legal action and often beyond’ (Uff 1996: 1).

Lack of client (owner) satisfaction with our built products is deeply troubling as well as being a major source of disputes and extra costs. Similarly, weak coordination within our industry, poor performance on the job site, and defects in the final product all contribute to poor public image and mistrust. While poor performance on the job site is not a mono-dimensional problem, it is a major underlying feature of flawed process that leads to unsatisfactory buildings and to customer dissatisfaction. One clearly identifiable aspect of poor performance is defective workmanship. This aspect is potentially remediable. To prescribe a remedy it is necessary to understand the cause.

INTRODUCTION

This paper is a compact partial summary of an extensive study to investigate causal factors of conduct underlying defective workmanship in construction as documented in the public sector in England/Wales (Barnes 2000). To exert a modicum of control, England and Wales operate under what can be called a conventional regulatory system having a subtle and loosely enforced impact outside the courts on how work is done.

METHODS

The basic investigation relied primarily on data from cases appearing in published law reports and public record transcripts of unreported cases. The category of such cases represents a small fraction of all cases brought into court (Carter 1996), since most disputants hopefully appreciate the probable value of early settlement. The collected data were limited by selection of those cases for reporting, the inconsistent focus of the reporting sources and by the variable conduct of the regulatory process. Unreported cases from 1990 to 1996 which were available in the Royal Courts of Justice Library, were also reviewed and appropriate transcripts chosen for the study.

The primary time frame of the base investigation is the 26-year period leading up to and through 1996. This period was been selected because of both the relevance of law and the availability of reference material in the jurisdiction of interest. While reference may be made to matters of influence prior to that time, the basic issues will be pertinent to that defined period. The data are drawn from an advancing frame of temporal and legal reference. While normalization of certain independent variables was assumed, the impacts of the conventional regulatory system of England and Wales are presumed to have been in force as prescribed by law. The distinction between conventional and unconventional systems is set by Blachere (1993) in discussing enforcement of building laws and regulations.

Eight human-based causal factors of defective workmanship were identified and assigned to identifiable features of the examined cases. These causal factors or characteristics define the sphere of cause considered in the study. See Table 1.

Eight architectonic sub-categories were established to bin the construction features of buildings/structures represented in the various profiled cases. These sub-categories define the sphere of construction activity considered in the study. See Table 1.

Eight categories were also defined for the legal doctrine or theory associated with each of the profiled cases, organized to permit multiple characterization where it is appropriate for conditions of the individual cases that have been profiled. See Table 1.

Construction disputes often lead to litigation that in turn fails to address the real source of manifested problems. These problems are often associated with technically unsatisfactory work products that are directly related to defective workmanship. While the underlying causal factors are sometimes identified and appropriate remedies prescribed, this is a remedy to compensate for the wrong, and the outcomes, though accessible to the public, are rarely made known in a constructive feedback manner.

A literature review focused on studies that address features of the construction process and completed product from the aspects of what kinds of things went wrong and what kinds of parties were responsible in what way. This was basically a review of relevant studies and condensed descriptions of influential writings that was an informative and productive concentration leading to structuring of a research methodology. Genesis of the causal classification system for the study was derived from this material.

The relevant law was described as not addressing defective workmanship in a specific manner but incorporated under numerous better defined legal theories and defended against by embodiment of broad performance requirement type language in statutes and contracts. The major strands of law affecting defective workmanship are tort, contract and statutory. The complex nature of tort law, especially negligence, as applicable to construction was discussed advancing to the then current state of English law as defined by the House of Lords in 1990 in *Murphy* v. *Brentwood Council* [1991] 1 AC 398.

The study employed a mixed quantitative and qualitative approach. The research was open-ended favouring grounded theory and analytical induction. Behavioural culture in construction was validated as an area that lacks significant exploration and resultant theory. The research considered settings and people holistically and sought a larger understanding from patterns in the associated data. A comprehensive presentation of numbers was suggested as having value in defining causal modes of significance.

The characterization and profiling of data from selected law cases led to structuring of an attribute table that in turn facilitated the search for themes and relationships. Thus the development from phenomena of an individual case to the structured presentation of many for analysis was realized. A common case report form eased compilation.

The choice of legal cases as the primary source of defective workmanship evidence is based on several facts. First, it is well known that although many contractors readily acknowledge the existence of the malady, few will willingly admit to or detail their own culpability in this area. Second, legal transcripts in whole or reported in part are an unimpeachable source of verity with regard to contractor performance. Third, the statements of judges in many cases speak directly to defective workmanship and its underlying causes, frequently coinciding with the study classification factors. And fourth, previous research and publication in this area by the study investigator found good reason to choose law cases as a major primary source of data for the study.

The phrase ‘work that is not done right’ begs the question of what is right. On the one hand we must deal with that which is legally right; or, if guided in a rule-bound manner to what is not wrong we can say that we have satisfied the letter of the law. The concept of right is a feature of culture and in our increasingly multicultural, ethically diverse and self-oriented society it is a concept of considerable fluidity and softness. What is all right for one is not so for another. In the complex philosophy of law and morality, Raz notes that our modern societies are characterized by moral pluralism that compounds the difficulties of predictable choice. In discussing various law and morality issues he also notes that the common law is regarded by the English middle classes as part of the English genius; but, '… working-class English people have traditionally felt that the law is not theirs but that of the upper classes'; and this is often manifested in a disregard for the law (Raz 1995: 310).

The subject of defective workmanship is recognized in many studies addressing the adjacent issues of defects, quality, cause and control, disputes, claims, and other matters associated with execution of the work. Notable among these are a handful by individuals who probed more deeply into the reasons behind the manifestations. They individually addressed different aspects of the defective work phenomenon and identified causal characteristics that have a remarkable unity. That unity led to factor selection. Those individuals or organizations are listed hereafter with major specific characteristics that they focused on or identified through broad surveys and research. The causal factor identity underpins the entire study and is discussed more fully here.

Porteus is exceptional among that above-mentioned handful in his focus on human error in the processes of construction. Porteus (1992) noted that his work, 'penetrated beyond the general terms "human error" and "negligence" to expose some details about the sorts of mistakes people make when designing and constructing buildings'.

Much was learned from selected writings on quality. Cheetham and Carter addressing the site execution of works note that many reports show workmanship as blameworthy as design and material specifications for failure. David Seymour in his many writings, notably in *Construction Management and Economics*, has provided abundant material. Low, who studied with Seymour, developed a keen understanding of the culture and incidence of defective workmanship (Low 1987). He gathered fact and opinion at many levels including assertions by the workers that they know what is to be done.

Features of interest to the base study that recurred in the primary literature have been listed below. Selected features and their author sources are listed. These were then distilled into a trial classification of conduct factors and a theory structure to promote orderly collection and reduction of data while testing selection of the factors.

1. Clegg (1992) – cultural environmental influence on site personnel (indexicality); poor communication; weak management/supervision.
2. Barnes and Mitrani (1994) – avoidance of financial responsibility by clients and first tier; improper job site procedure; poorly conducted management, weak management/supervision; use of court records as information source; lack of knowledge; poor communication; poor workmanship; contract not understood; overemphasis on first cost (greed).
3. Watts and Scrivener (1993) – use of court records as information source; sources of dispute: site and execution of the work; quality; payment; negligence; damage claims.
4. Porteus (1992) – natural causes vs. human nature; human error, sometimes called negligence; poor communication; dereliction or negligence; ignorance or lack of knowledge; overemphasis on first cost.

5. Burati and Farrington (1992) – erroneous methods or procedures; omission of activity or task.
6. Thornton (1986) lack of knowledge; blunders, errors and omissions; overemphasis on bottom line; lack of supervision; poor communication.
7. Knocke and CIBW87 (1993) – unforeseeable human action; errors and omissions.
8. Cheetham and Carter (1993) – lack of good practice compliance; weak coordination (communication).
9. Page/Murray (1996) – poor supervision; faulty workmanship; widespread ignorance; negligence; and cost-cutting practices.
10. BRE Report (1990) – inadequate skill and knowledge; importance (lack) of site supervisor experience.

Applying the features specified or probable/possible in the numbered sources to a trial list of factors assumed from the literature and contextual research, the base study found a nominal distribution that gives verification to the selection of at least four of the factors. Bold type indicates direct reference to that feature in the represented source, normal type indicates a probable or possible reference or implication.

Causal factors	*Source*
Comprehension of scope	**2**
Lack of knowledge	**2**, **4**, **5**, **6**, 7, 8, **9**, **10**
Excessive haste	**2**
Simple greed (incl. overemphasis on first cost)	**2**, **4**, **6**, 7, **9**
Poor communication (poor coordination)	**1**, **2**, **4**, 5, **6**, 7, **8**
Weak estimate	**2**
Weak supervision	**1**, **2**, **4**, **5**, **6**, 7, **8**, **9**, **10**
Weak finance	**2**
In two of the same examined literature the use of court records was found workable	
Use of court records as information source	**2**, **3**

Despite its pervasive nature in underlying many unsatisfactory features of buildings and other structures that eventually become subject to dispute, the fault of defective workmanship does not have its own designated niche in the law. True, it is implied in defective products, and it is referred to generously in the common law. It is even written into statute such as requirements within the Defective Premises Act 1972 (applying to dwellings only and infrequently invoked), and the Building Act 1984 which authorizes building regulations that may prescribe the manner in which work is carried out (see Building Act 1984, Schedule 1). The Building Regulations 1991 as amended and incorporating regulation 7 dealing generally with workmanship, and the application of BS 8000: *Workmanship on building sites*, Parts 1-1, flow from that latter authority. In spite of such emphasis and its frequent relevance to litigation, defective workmanship *per se* is not recognized as a separate tort. A tide of tort actions however, usually based on negligence, has ebbed and flowed over the years as guided by decisions of the courts.

Given the lack of a specific niche in the law for defective workmanship, it can also be found that as a specific subject, defective workmanship has not been widely discussed or researched by academia or the legal community. There are the excellent studies focused on the technical nature of defects as commissioned by government; and, exceptionally, Duncan Wallace, in *Hudson's* devotes much attention to defective work (Duncan Wallace 1995).

Contract is one major strand of law under which obligations arise for defective workmanship. It also imposes statutory obligations such as compliance with the building regulations. The terms of contract law are relatively easy to understand. If you agree to certain terms, you are obliged to satisfy them. Failure to do so entitles other parties to the agreement a favourable position for negotiation or legal remedy.

Tort, as the second major strand of law threatening defective workmanship, is less easy to understand. John Uff notes, 'Tort can be defined as a civil wrong independent of contract; …' (1996: 415). Simple! But in spite of the independent nature, the law of tort is still part of the control framework for getting a project done. That is an easy way for the contractor to think of it; as an essential code or set of conduct guidelines.

In talking about research in the construction industry, Fellows (1997) notes that, 'very little research has been done to determine the culture of the industry – the values and beliefs which govern people's behaviours'. Values, beliefs and shorter term stimuli such as leadership or lack thereof can determine immediate behaviour. Bad workmanship is a manifestation of behaviour in specific settings.

It was determined that a multidimensional array was necessary to characterize the various cases under study. Three organizational fields of indices were identified as appropriate measures of defective workmanship with each given eight sub-categories to assist in classification of cases through notation of incidence occurrence.

Table 1

Architectonic*	**Causal**	**Legal**
Soils, foundations	Scope comprehension	Fraud
Substructure	Lack of knowledge	Misrepresentation
Superstructure	Excessive haste	Breach of contract
Envelope/cladding	Simple greed	Negligence
Roofing	Poor communication	Nuisance
Services	Weak estimate	Statutory breach
Finishes/specialties	Weak supervision	Warranty breach
Temporary structures	Temporary structures	Trespass

*A term used here to indicate architectural or construction location.

In discussing theories of ill-defined behaviour, Cohen (1995) noted, 'We can often recognize phenomena long before we can define them, and many important phenomena have been studied for years without benefit of a consensual opinion.'

Neil Pepperell (1991) noted that much of our inability to stem the flow of defective work is tied to our failure to articulate clear definitions of quality. Although much of the work he describes parallels the BRE concentration on technical aspects of defects, Pepperell does acknowledge that a significant grey area exists in designation of responsibility for defining technical standards, and moreover, in organizing the supervision of their implementation.

That latter weakness is discussed frequently by I.N. Duncan Wallace in his many writings. It is puzzling that an issue championed by such an authority as needing attention has received so little. In one of his more colourful articles Duncan Wallace takes sharp aim at current practices that have encouraged rather than discouraged defective work. Namely, he cites four lines of thought or proposition that include: passive contractor attitudes that are buttressed by industry-commissioned reports identifying design deficiencies as the major factors; consistently ineffective contractual remedies; failure of governmental authorities to establish the proper measure of control and regulatory enforcement; and lastly, attempts to finesse the root causes of defective work by insuring against it and passing the cost on to the consumer. He rightly dismisses this latter proposal as another red herring to draw attention away from the contractors' failures and blames a 'producer-oriented government' for not taking firmer control. He is one of the few who have recognized the pernicious effect of indifferent and evasive contractor attitudes concerning supervision of the work. Further, he has identified potentially corrective action; e.g., 'surely the function of contractor supervision, whether by contract or site managers or agents, or by general foremen, is in a modern society far too important a task to be left to individuals who are not necessarily either licensed or qualified' (Duncan Wallace 1990).

Duncan Wallace (1986) does not dance around the issue of responsibility by positing the architect, supplier, local authority or central government as culprit. He lays much of the blame directly on the contractor and subcontractor, who historically have worked successfully to shift the balance of blame for defective work away from themselves and on to the other parties.

The stage was set for analysis of defective work undertaken in the base study by a case clearing the House of Lords in October 1965. In *East Ham Corporation* v. *Bernard Sunley and Sons* a successful appeal of the Court of Appeal reversal returned a breach of contract judgment for defective work. The presiding judge in appeal noted widespread faults in stone panel fixings that ultimately required re-fixing or replacement. (*East Ham Corporation* v. *Bernard Sunley and Sons* [1966] AC 406; [1965] 3 WLR 1096; 3 All ER 619; 2 Lloyd's Rep. 425, HL; reversing [1965] 1 WLR 30.)

In the first decade of the study time frame, selected residential cases out-numbered those of a commercial or industrial nature almost two to one. Defective foundations and/or soils dominated the architectonic characteristics of the early decade cases.

The second decade brought a reversal of the building type reflecting dominance of defective workmanship with commercial and industrial appearing two to one versus residential in the selected cases.

In the mid decade from 1980 to 1989, just three of 29 selected and charted cases sounded in contract only. The other 26 were characterized by tort alone or tort and contract jointly.

The final decade (albeit a partial one) of this study time frame is from 1990 to 1996. This period encompassed the end of the *Anns* doctrine and saw, after *Murphy*, a dominance of contract over tort as the legal theory of choice and success. (*Anns* v. *Merton LBC*; *sub nom*. *Anns* v. *Walcroft Property Co Ltd* [1978] AC 728; [1977] 2 W.L.R. 1024, HL.)

The decision of the House of Lords in *Murphy*, a defective design case, brought about a realignment of thought in the legal community. As mentioned previously, lawyers began to focus on framing causes of action related to contractual or statutory obligations. The time limitations for these actions became more meaningful as the alternative opportunities for successful litigation were greatly diminished (*Murphy* v. *Brentwood Council* [1991] 1 AC 398).

FINDINGS

The findings resulted in numbers that have been aggregated in summary matrix tables. Those summary aggregations were used in contingency tables to interact and generate further numbers exhibiting high count intersections of defective workmanship causal conduct modes. The high value intersections represent areas of consideration for preventive measures and enhanced performance. All intersections are represented in causal conduct vectors across the variables of architectonic location and legal theory. All of the cases representing numbers in the matrix tables were analysed thoroughly and a brief prepared citing numerous classification features such as the judge, court, date of incident, job venue, contract amount, construction period and contract type. Issues and outcomes were discussed with relevant quotations from witnesses, counsel, principals and the judges. Owing to space limitation, only an end summary appears here.

Table 2

CONTINGENCY TABLES - ENGLAND/WALES

		ARCH ID										LEGAL								
		Soils, Foundations	Substructure	Superstructure	Envelope/cladding	Roofing	Services	Finishes	Temp Struct/Rigging	All Architectonic 1-8		Fraud	Misrepresentation	Breach of contract	Negligence	Nuisance	Statutory breach	Trespass	Breach of Warranty	All Legal 1-8
CAUSAL FACTORS	xxxxx	1	2	3	4	5	6	7	8	Vector Sums		1	2	3	4	5	6	7	8	Vector Sums
Scope comprehension	1	**1**	**1**	**1**	**2**	**2**	**1**	**2**	**1**	*11*		**0**	**0**	**6**	**3**	**0**	**0**	**0**	**0**	*9*
Lack of knowledge	2	**9**	**3**	**11**	**12**	**6**	**6**	**8**	**2**	*57*		**1**	**1**	**23**	**29**	**1**	**5**	**1**	**0**	*61*
Excessive haste	3	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	*1*		**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	*1*
Simple greed	4	**6**	**3**	**4**	**4**	**2**	**1**	**1**	**0**	*21*		**2**	**1**	**5**	**10**	**0**	**4**	**0**	**0**	*22*
Poor communication	5	**5**	**2**	**10**	**10**	**4**	**9**	**6**	**1**	*47*		**0**	**0**	**21**	**16**	**0**	**2**	**0**	**0**	*39*
Weak estimate	6	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	*0*		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	*0*
Weak supervision	7	**15**	**6**	**16**	**19**	**8**	**7**	**9**	**1**	*81*		**3**	**1**	**32**	**36**	**1**	**6**	**1**	**0**	*80*
Weak Finance	8	**0**	**0**	**1**	**1**	**1**	**1**	**0**	**0**	*4*		**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	*1*
	SUM	36	15	43	48	23	25	27	5	*222*		6	3	89	94	2	17	2	0	*213*

A simple table arrays the high vector sums in a more readable manner.

Table 3

Causal f (Architectonic)	England/Wales		**Causal f (Legal)**	England/Wales
Weak supervision	81 / 36.5%		Weak supervision	80 / 37.6%
Lack of knowledge	57 / 25.7%		Lack of knowledge	61 / 28.6%
Poor communication	47 / 21.2%		Poor communication	39 / 18.3%
Simple greed	21 / 9.5%		Simple greed	22 / 10.3%

It is easy to conclude that these four causal characteristics listed above represent conduct problem areas for construction project managers and companies.

Moving forward in time from the base study, important incidents occurred beginning in 1996 which altered the complexion of legal treatment that defective work issues would be subject to. The Housing Grants, Construction and Regeneration Act was passed and affected construction contracts after 1 May 1998. Section 108 of that Act established adjudication and gave parties a right to refer disputes to a mandatory procedure defined in the Act. On 9 October 1998 the Official Referees were replaced by judges of the Technology and Construction Court. On 26 April 1999 the Rules of the Supreme Court and County Court Rules were replaced by the Civil Procedure Rules. The CPR have been updated constantly since that time with the latest revisions of the Pre-Action Protocol for Construction and Engineering Dispute and the Pre-Action Protocol for Housing Disrepair Cases. In general, these latter encourage early cooperation between the parties in the interest of early settlement without or with minimal litigation. Revised rules on costs, claims and counterclaims are also of interest and they along with the protocols all impact on defective workmanship issues that might rise to the level of litigated cases (Anon 2006). Also, there has been a further strengthening of case law stressing the understanding of relevant contractual language as a reasonable person would versus literal interpretation of unclear words as cited in *Keating* (Anon 2006: 3-023). Whatever the underlying reason or reasons may be, there seem to be fewer law reports dealing substantively with defective workmanship.

A preliminary review of the law reports since 1998 reveals numerous cases of pertinence to this study, major and minor in nature, that reflect defective workmanship. With the three from the base study not included in its tabled results, they together indicate continuation of the earlier pattern highlighting causes of supervision, knowledge and communication. Those further cases reflecting significant defective workmanship include the following at a minimum: *Department of National Heritage* v. *Steensen Varming Mulcahy, Balfour Beatty Ltd, Laing Management Ltd* [1998] EWHC Technology 305; *Baxall Securities Limited* v. *Sheard Walshaw Partnership* [2002] EWCA Civ 09; and *Catlin Estates Limited* v. *Carter Jonas* [2005] EWHC 2315 (TCC). A detailed study of this more recent period will be presented in the future.

CONCLUSIONS

Since at least the time when the Code of Hammurabi prescribed one-for-one comparable restitution or penalty for defaulting contractors, humankind has struggled with discouraging and preventing defect-associated faults, and controlling contractor performance. The institution of strong mechanisms and a culture of professionalism is needed to establish and foster control of contractor performance. To the credit of the industry, such measures have been initiated on many fronts. The rub arises in human nature. The simple act of working for hire inspires some to do their best, strive for excellence, and achieve a high level of performance. Some do this of their own accord, others respond to leadership. Others need urging or goals or requirements.

The dark side of reality is that there are those who are seldom motivated to do their best, even if they know what they should do. They are often working for wages and the profit motive does not reach them; or, they are focused on short-term gain. Thus, in respect of work not being done properly, we must acknowledge that there are many within the workforce that lack either the motivation to do well, or the knowledge of how to do it, or both. The need to accommodate this phenomenon arises constantly in an industry that in recent times has been ill equipped to handle it, and is under constant pressure to produce work in a timely and cost competitive manner.

Finally, there is the greed for money above all else, and the tragic end often arrived at by the contractor with an unbridled profit motive shaving quality or hiding bad work in an attempt to get done with the least effort and cost. Understandably, the subject of bad workmanship is not one that contractors will talk about readily. They are especially loath to do so when the discussion involves their own operations or labour forces.

As do other arenas of endeavour in life, the construction industry attracts both the best and the worst of human qualities. Ingrained cultural attitudes are difficult to change. There has been much discussion of contractor licensing or accreditation in the British construction industry. Such a mechanism could be very beneficial if it were devised to address all levels of activity, and if it were enforced to protect the general public whether they be homeowners, corporations or a government department.

Access to the records of dispute resolutions out of court is privileged and not available to this study. Despite that, and although the costs of resolution are better controlled and the impact on the courts seems to have been lessened through adjudication, the evidence in law reports remains and defective workmanship is still very much alive.

REFERENCES

Anon (2006) Chapters 17 and 18. and at 5-023. *In:* S Furst and V Ramsey (Eds.) *Keating on construction contacts.* 8ed. London: Sweet & Maxwell.

Barnes, W (2000) *Defective workmanship: a transatlantic analysis of construction law and practice*, Unpublished PhD Thesis, University of Central England.

Barnes, W and Mitrani, J (1994) Practices in the construction industry that lead to legal problems: phase three. Tech. Publ. 114, Dept. of Construction Management, FIU.

Blachere, G (1993) The role of national governments in risk reduction. *In:* J Knocke, CIB (Ed.) *Post-construction liability and insurance.* London: E & FN Spon.

BRE-Anon (1990) *Rehabilitation: a review of quality in traditional housing*, Report, Building Research Establishment.

Burati, J, Farrington, J and Ledbetter, W (1992) Causes of quality deviations in design and construction. *Journal of Construction Engineering and Management*, **18**(1).

Carter, R (1996) Note: personal interview (Rota Clerk Official Referees Court).

Cheetam, D W and Carter, D J (1993) The challenge of assuring quality on site. *Building Research & Information*, **21**.

Clegg, S R (1992) Contracts cause conflicts. *In:* P Fenn and R Gameson (Eds.) *Construction conflict management and resolution.* London: E & FN Spon.

Cohen, P R (1995) *Empirical methods for artificial intelligence.* Boston: MIT Press.

Duncan Wallace, I N (1986) *Construction contracts: principles in tort and contract.* London: Sweet & Maxwell.

Duncan Wallace, I N (1990) Defective work: the new flavours. *Construction Law Journal*, **6**.

Duncan Wallace, I N (1995) *Hudson's building and engineering contracts*, Vol. 1. 11ed. London: Sweet & Maxwell.

Fellows, R. (1997) *Research methods for construction.* Oxford: Blackwell Science.

Knocke, J (Ed.) (1993) *Post-construction liability and insurance.* London: E & FN Spon.

Low, S P (1987) *An evaluation of quality and workmanship in construction*, Unpublished MS (Engr) Dissertation, University of Birmingham, Edgbaston.

Page, C and Murray, P (1996) An analysis of structural defects occurring in residential building in the East Midlands region. *Structural Survey*, **19**(2), 35–40.

Pepperell, N (1991) Construction defects research. Paper presented at the CIB W87 7th Plenary Meeting.

Porteus, W A (1992) Classifying building failure by cause. *Building Research and Information*, **20(**6), 350–6.

Raz, J (1995) *Ethics in the public domain.* Oxford: Clarendon Press.

Thornton, C (1985) Failure statistics categorized by cause and generic class. *In:* A Dib and J Grant (Eds.) *Interdisciplinary treatment of construction failures, legal handbook for architects, engineers and contractors,* Vol. 1. New York: Clark Boardman.

Uff, J (1996) *Construction law.* 6ed. London: Sweet & Maxwell.

Watts, V and Scrivener, J (1993) Review of Australian building defects settled by litigation. *Building Research & Information*, **21**, 59–63.

BOOK REVIEWS IN CME: A CRITICAL PERSPECTIVE

David Langford[1] and Mike Murray [2]

1 School of the Built and natural Environment, Glasgow Caledonian University, Cowvcaddens Road, G4 OBA, UK
2 Department of Civil Engineering, University of Strathclyde, 107 Rottenrow, Glasgow, G4 ONG, UK

This paper analysis the book reviews appearing in five volumes of *Construction Management and Economics* (Vols 20–24). This provided a sample of 52 reviews. It analyses each review in two ways: firstly, by the factual information about the published book. These include the subject area of the books published, who publishes them, the balance between edited and written books, the price range and pence per published page by each publisher. The second part of the analysis relies upon an interpretive framework. Each review is assessed for its qualities of being informative about the content, purpose and audience for the book under review. Additionally the review will be evaluated by reference to its critical facility and whether the review offers an uncritical perspective or offers a more engaged opinion. Finally, the reviews are assayed by whether its reviewer recommends the book to its stated or perceived audience.

Keywords: Book reviews.

INTRODUCTION

Books are a major resource that sustains an academic discipline. They provide a framework of scholarship from which students and other aspiring professionals learn their trade. They also provide a valuable accessible shortcut to the wealth of research that underpins an academic discipline. Books provide the instruments for sifting and evaluating research. In all, books are important. Consequently, the evaluation of books published will be a critical academic task in support of a discipline. This paper evaluates 52 book reviews appearing in *Construction Management and Economics* (*CME*) over the period 2002–2006. It undertakes a quantitative review of who publishes, what is being published, how much each publisher charges per page of published work, the trends in the books being published in terms of specialism and forms of production. The second part evaluates each review on three subjective criteria: how informative are reviews, how supportive are reviewers and whether the reviewer recommends a book to readers. The piece is notable for the absence of references to other work.

There is little literature available on how to review books and an extensive literature search only revealed works by Orwell (1968) who commented upon the nature of book reviews. He notes that Chesterton (1968) identified a distinctive category of book, which he called a good, bad book. These are books with no literary pretensions, but are extremely readable books and so found a place because of the sheer natural grace, erudition or intellectual power evinced by the writing, Orwell comments that there are no literary tests to show where superiority lies. The formation of an opinion should involve academic ascetic judgement and a view of whether the book is worth buying. Orwell celebrates the prose of music hall and playfully says that musical songs are better than many of the poems appearing in formal anthologies. He cites:

> Come where the booze is cheaper,
> Come where the pots hold more,
> Come where the boss is a bit of a sport,
> Come to the pub next door!

A more sombre Orwell (1968) writes in an essay entitled "Confessions of a book reviewer" where he presents reviewing as a less than joyous task especially when confronted with reading about which he knows little and earns less. He wants to write a review saying that a book is worthless and that "the great majority of reviews give an inadequate or misleading account of the book". Orwell's ennui with reviewing leads him to conclude that specialist reviewers are required for specialist books and invariably this is the practice in CME book reviews.

In a further exploration of reviews, Orwell (1968) undertakes a meta-review of Penguin books as a distinctive category of publishing. He comments upon the personal economics of book buying and this will be considered further when publishers are compared in respect of price per page of published work.

More recently, an essay appeared in the *Spectator* by Max Hastings (2006), the military historian who compares the practice of book reviews with that of critics of theatre and other performance arts. He argues that book reviewers are much gentler than the critics of performance arts. He speculates that the reason for this is that the film critic has no aspirations to be a film director or a movie actor; similarly, the theatre critic does not seek to be a playwright. However, the book reviewer is likely to be drawn from a small circle of known writers with literary editors commissioning known authors to review books to appear in the review section of the daily or Sunday newspapers. Hastings sees this as a complicit circle; authors are reviewers and reviewers are authors. Consequently, reviews are gentle since all know that the boot is going to be on the other foot at some stage in someone's career. The literary world is notable for falling out after bad reviews have been published, perhaps the most notable being between V S Naipaul and Paul Theroux after Theroux had savaged one of Naipaul's books.

Recognizing the pitfalls of reviewers and critics being drawn from a closed circle, Young (2007) argues that the critic needs some distance from expertise in the subject under review in order to offer a populist rather than expert opinion on what is being reviewed.

This antagonism between author and critic is explored by Smith (2007a 2007b), who takes to task book reviewers she believes to be too cynical. She calls for non-cynical criticism that reveals the personal tastes of the reviewer. Her view is that for books to be well received by reviewers they have to confirm to a "shared view of entertainment" often shaped by television sit-coms, thus 'representing' an incurious reader.

The nub of the argument is that book reviewers are gentle and fear retaliation for delivery of a bad review. This retaliatory power will surely temper the ferocity of any review, although the social bond between reviewer and author may only be a backcloth to the review. Other, more obvious, stimulants to a mild or enthusiastic review may be at work. The review may accurately reflect the reviewer's opinion of the book. Other reasons for soft reviews may pertain. The sense of 'usefulness' of the book to the reviewer may be influential on the delivered reviews. As will be seen later, practitioner reviewers are frequently more caustic because they are looking for something beyond that which may be seen as useful to an academic audience.

The books reviewed in *CME* from volumes 22 to 24 provided the sample. The reviews are inspected for certain characteristics. These included the style of review, how informative the review was, how supportive is the reviewer of the ideas carried by the book and, the acid test, does the reviewer recommend the reader to buy.

In a small and tightly knit construction-management community, reviewers are seldom unknown. Reviewers need to be authoritative and well informed, and these conditions come about by mixing with others in the discipline. Inevitably, we will be invited to review books by friends and the need to retain critical faculties in such circumstances is paramount.

STYLE OF REVIEW

Whilst there is limited evidence of a set of rules for book reviewing, certain axioms may be stated:

- Whilst reviews are seen as a part of marketing, they should not be ‘selling’ to the reader.
- The reviewer should not show off their knowledge but offer an opinion on the work under review
- A degree of academic and ascetic judgement must be shown.
- The reviewer must be cognisant of the stage of career development of the author.
- Finally, is the book worth buying?

These axioms are often prosecuted through the medium of metaphor and wit.

These are the artifices that are used frequently by reviewers; metaphors are used to convey an impression of the work under review. Such a vehicle enables wit to embellish the review.

Of the 52 reviews constituting the data for this paper, only one used the metaphor technique to convey to the reader an understanding of what a book was about. Indeed, only two reviews drew upon sources beyond the book itself. Of these two, only one referred to concepts beyond the scope of the construction literature. Why might this be the case? A number of reasons come to mind. Firstly, the audience for reviews appearing in more mainstream publications are rather different to that of *CME* where the audience will be largely drawn from ones peers. The reviewer may feel exposed if a jocular style is presented. Secondly, a more flippant review may be taken as insulting to the quality of work under review. Reviewers may naturally be cautious about giving slight to colleagues in what is a relatively tight knit community. Thirdly, the commissioning process for reviews will be different. Books reviewed in the mainstream press will have been selected by the literary editor or such like. Such selectivity is unlikely to be the case in *CME*. Whilst editors may select reviewers who will deliver an interesting and lively review, the scope for this is likely to be diminished in the case of CME. Fourthly, in order to use metaphors there needs to be a commonly understood culture, and whilst newspapers will have an international audience, they are produced largely for domestic consumption. The international span of *CME* may obviate against the use of metaphors in reviews since a common understanding of what is being signalled by a metaphor may not be obvious. Finally, do we have the confidence to break out of the restrictions of academic writing?

DOMINANT CONTROL WITHIN A COMMUNITY OF PRACTICE

The concept of retaliatory power with respect to how complementary or derogatory a review is has been noted above. The CME community is without doubt international in nature and through associated activities (i.e. ARCOM, CIB conferences, sister journals) its participants are aware of key players within interest groups. As the community evolves in membership, degree of participation and scholarly interests, tensions between members may be evident. Although rarely explicit, such tensions are normally played out through critical attacks on research activity (i.e. validity of methodology, conclusions etc.) that is often reflected in the process and outcome of peer-reviewed journal papers. This tension may also be explicit regards the success of funded research proposals and in doing so suggests another control factor within the community.

If we are to consider the research groups responsible for work in specific topics (i.e. procurement, culture, innovation, project management, finance, human resource management) then participants within the community would be likely to name two to three of those who hold influence in such scholarly work. It could be considered that these individuals have a referent power within the community that is of particular importance with regards book reviews. However, an excessive number of reviews glorifying each others work has the potential to lead to "the scene that celebrates itself" whereby cliques within the community are reliant on each others positive endorsement. Employing construction practitioners to undertake reviews would be a useful approach in reducing this potential bias.

THE PRICE OF BOOKS

A crude analysis of the price per page of books across a range of publishers is presented. But this does not answer the question – what is a fair price? Again, Orwell (1968b) makes some interesting points when reviewing the contribution of Penguin books to the publishing world. He notes, "If you have £2 to spend on books, and the book price is £1, you may buy two books. But if the books are 20p, you are unlikely to buy 10 books, because you don't want as many as that. Saturation point has been reached before you get to 10. You may buy three books and spend the other £1.40 on something else. Hence, the cheaper books become, the less money is spent on books. This is to the advantage of the reader and trade as a whole, but for the publisher, bookseller and author it is a disaster."

Table 1 shows large differences in the price per page of books from different publishers. The data takes no account of the variables that will shape the price: issues such as hardback and soft back editions, the number of any previous editions, the quantity of graphic and tabulated material etc. These production-related issues will be influenced by the perception of the publisher of how well the book will sell – matters such as quality of writing and the 'must-have' utility of the information presented by the book. For example, a copy of the Building Regulations is likely to sell well because it is a 'must-have' book for every profession, whilst a book such as 'finite element analysis in designing tall structures' (a made up title) is seen to have fewer sales since its imparted knowledge is likely to be understood by fewer people. These factors may guide publishers to a price but Table 1 does not explore the cost of production for each book. These may vary greatly. It is presented mainly as a matter of passing interest and something that may stimulate further investigation.

Table 1: Publishers and prices of books

Publisher	No. of books	Sample	Average Price p/page	Range of Price p/page
Blackwell	23	22	£0.12	£0.05–0.20
Spon	6	4	£0.16	£0.16–0.18
Various university presses	5	4	£0.11	£0.07–0.19
Thomas Telford	4	3	£0.24	£0.20–0.29
Palgrave MacMillan	3	3	£0.06	£0.05–0.07
CIRIA	2	2	£0.38	£0.31–0.46
Professional bodies & charities	2	2	£0.34	£0.26–0.62
Other publishers with one publication	9		£0.17	£0.02–0.45

THE TRENDS IN WHAT IS REVIEWED

Whilst a more convincing story could be told by using publishers' catalogues as a database, it is interesting to review the trends of the specialist books that have come under review in *CME*. The purpose of this analysis is to see if certain subjects grow or diminish in popularity over the five years.

The range of subjects is shown in Table 2. Volume 20 reviews the most books and so, unexpectedly, the range of subjects covered is the widest with 11 of the 14 categories being covered. The most written about specialism is project management, shortly followed by economics and finance, and sustainability – all three of these categories have books reviewed in every volume within the survey. There are important signifiers of the interests of the construction management community.

If we consider the driving force behind these trends, it is evident that academia has continued to seek publications that reinforce the need for inquiry. This is self sustaining and perhaps reflects the belief that such textbooks inform practice within industry as opposed to documenting it. Of course, one could not argue that these books are vehicles for dissemination. However, it is rare occurrence to hear of any construction textbook described as seminal or groundbreaking. This is in contrast to other texts (i.e. Womack *et al*.'s (1991) *The Machine that Changed the World: The Story of Lean Production)* that, rightly or wrongly, have been regarded as essential reading for construction CEOs.

WRITTEN OR EDITED? BY WHOM?

There has been a trend towards 'editing' in preference to 'writing' books over the period under review. Within the sample, eight books carry the notation that the writers have edited the volume and the underlying trend is that edited books appear in the later years of the sample (three of the eight in 2005). The editorial roles are conducted invariably by academics. Yet, practitioners are active in several books: practitioners wrote 10 of the sample, whilst academics contributed 32 (10 books were unassigned in the category as the author's affiliation was not available). Only one book could be codified as being produced by an academic and practitioner working together. This is surprising given the exhortation by government, industry and academics that research partnerships are needed between practice and the academy. The output of jointly presented research papers may have flourished in this environment, though this has not transferred to scholarship.

Table 2: Trends in what is reviewed

	Communication	**Construction Technology**	**Design**	**Economics & Finance**	**General Reader**	**Innovation**	**International**	**Law**	**Partnering**	**PFI /PPP**	**Procurement**	**Project management**	**Research Methods**	**Sustainability**	**Total**
Volume 20 (2002)		1	1	2	1	1	2	1	1	1		2	4	2	9
Volume 21 (2003)				3	2	1				1		2	2	2	13
Volume 22 (2004)	1			2							1	2		1	7
Volume 23 (2005)			1	2		1			1	1		3	1	3	13
Volume 24 (2006) Incomplete series				1										1	2
Total	1	1	2	10	3	3	2	1	2	1	3	11	2	9	

EVALUATION OF REVIEWS

The dominance of academics amongst the reviewers is overwhelming: 40 of the reviews are presented by academics and only seven by practitioners. Five reviews could not be categorized. The practitioners are notably more hostile when compared to academics. When tested against the three criteria that had been selected to evaluate the reviews (informative, supportive and recommended), only eight affirmative reviews out of 21 were given (38%) and five reviews could be classed as hostile to the work under consideration.

This compares to the academic sample, which reported 88 approvals against 32 negative opinions (73% approvals) assigned to the informative, supportive, recommended criteria. Reviewers from the academic group did not recommend 10 of the 40 books reviewed. Practitioners did not recommend four of the seven books under scrutiny. Those with unknown affiliations were receptive to the book under review 12 times out of 15 (80% approvals).

Although these are small samples, there are clear differences between the perceptions of reviewers from industry and those from academia. Why might this be? Several factors may be at work. The first explanation may lie with the dual role of author and reviewer. At least 19 of the reviewers are known to have authored books. This section of the reviewing population was particularly sympathetic of others, providing 41 approvals out of a possible 57 (72%). Knowing that the boot is to be on the other foot on some future occasions may act as a powerful brake on acerbic criticism. Secondly, the social relationships that exist inside a small and tight knit academic community may deter a ‘no-holds-barred’ approach. Even if reviewers are not authors or have no intentions to be authors, the sense of being part and needing to be part of the academic community may blunt critical comments. Clearly, the practitioner reviewers do not feel constrained by this social cohesion since their reviews are much harsher.

CONCLUSION

The review of new books within learned journals provides a community of practice with an opportunity to disseminate new knowledge. The purpose of a review is to provide an objective critique of the works whilst seeking to fulfil several, often competing objectives. The book authors, editors wishing for a healthy recommendation, as are the publishers, whilst the academic community at large may be looking for possible course textbook recommendation. What is unknown is the degree to which reviews are tempered as a result of the social and professional bonds within the *CME* community. Aside from the social issues, it may be that academics write books to be read by other academics and so a sympathetic review is a statement of confirmation of membership of a ‘tribe’. Although no evidence of such bias is evident, it would be naive to ignore this as a potential control factor, explicit or implicit, over the community. As was noted, the few practitioners who were commissioned to undertake reviews were notably less supportive in their critique. Perhaps this suggests the usefulness rating of textbooks for this group is wanting. This would be a disappointing conclusion and particularly so given that the Fairclough (2002) report sought to ensure more substantial collaboration between industry and academia. One solution that may find an appropriate home would be for CME to employ dual reviewers with both practitioner and academic seeking to rate the textbook over such variables as ‘innovative’ ‘potential for knowledge transfer’ and ‘usefulness for academics and practitioners’. This would provide some cover to the academic within the CME community – akin to the anonymity of a soldier using one bullet in a firing squad (albeit with only two actors) – and may encourage a deeper critique.

REFERENCES

Fairclough, J (2002) *Rethinking Construction Innovation and Research: A Review of Government R&D Policies and Practices*. London: Dti.

Hastings, M (2006) Don’t spare the boot. *Spectator*, 24 June, 46.

Orwell, G (1968) *In:* P Davidson, I Angus and S Davidson, S (Eds.) *The Collected essays, journalism & sketches of George Orwell 1903–1950*. London: Secker & Warburg.

Smith, Z (2007a) Fail Better, *Guardian*, 13 January, 4.

Smith, Z (2007b) Read Better, *Guardian*, 20 January, 21.

Young, T (2006) Chorus of disapproval. *Spectator*, 15 December, 88.

Womack, J P, Jones, D T and Roos, D (1991) *The Machine that Changed the World; the Story of Lean Production*. New York: Harper Perennial.

Index of authors

Keywords

D

E

F

G

H

P

Q

R

S

T

U

V

W