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THE PRICE OF RISK IN CONSTRUCTION PROJECTS: CONTINGENCY APPROXIMATION MODEL (CAM)

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Abstract

Little attention has been focussed on a precise definition and evaluation mechanism for project management risk specifically related to contractors. When bidding, contractors traditionally price risks using unsystematic approaches. The high business failure rate our industry records may indicate that the current unsystematic mechanisms contractors use for building up contingencies may be inadequate. The reluctance of some contractors to include a price for risk in their tenders when bidding for work competitively may also not be a useful approach. Here, instead, we first define the meaning of contractor contingency, and then we develop a facile quantitative technique that contractors can use to estimate a price for project risk. This model will help contractors analyse their exposure to project risks; and help them express the risk in monetary terms for management action. When bidding for work, they can decide how to allocate contingencies strategically in a way that balances risk and reward.

Keywords: contingency, contractors, risk exposure, risk pricing, uncertainty.

1. Introduction

Quite often, construction contractors are unable to effectively price for the risk in construction projects. Common risks contractors face include weather, unexpected job conditions, personnel problems, inflation, price fluctuations, errors in cost estimating and scheduling, delays, financial difficulties, workmen strikes and agitations, faulty materials, cash flow, contractual disputes, faulty workmanship, poor supervision, new regulations and legislation, operational problems, currency exchange rates, inadequate designs and specifications, politics, disaster, etc. Even where contractors are able to somewhat assess risks, they are often reluctant to price this into the bidding price when they bid competitively [17]. Contractors can respond to risk before the construction of a project or after; they can choose to forecast a price for risk based on all information available at the tender stage and account for it in the bid or overall business strategy, or they can be indifferent and count the cost of risk in severe losses after a contract. The problems of risk assessment are complex and poorly understood in practice. But little attention has been focussed on an evaluation mechanism for project management risk specifically related to contractors. This paper is the starting point for the development of a robust but practical model (CAM) that contractors can use when pricing to build up contingencies into the estimated costs of construction. Formal models have proliferated in recent years but they are mostly unused in practice. This practically oriented model can help contractors minimise the problem of arbitrary contingency allocation. They would be able to analyse their exposure to risks, and then express the risk value in monetary terms.

2. Background

In 2004, the Druml Group in the USA (www.drumlgroup.com) published a report on fifty-six risk factors that can make or break construction companies. The authors observed the emergence and demise of many prominent construction companies throughout history, and wondered why the construction industry --- a significant part of national economies --- was so volatile. One possible reason they attributed to this phenomenon was that whilst many construction contractors have learned to master building, they have failed to master risk. An essential requirement for successful contracting is the effective evaluation of risks, followed by sound decisions based on the evaluation, and appropriate action taken because of these decisions [14]. If the monetary loss resulting from risk events is not considered or is underestimated due to associated uncertainties, a construction enterprise may suffer a tremendous loss and eventually fail.

In recent years, formal and analytical risk models that contractors can incorporate into the bidding process to assess project risk have proliferated. However, they are not patronized in practice. Contractors traditionally rely on unsystematic mechanisms such as intuitive judgment, expert skill, and experience to assess and allow for project risk when pricing tenders. Experimental studies of 30 contractors in the USA by [13] sought to investigate two issues: (1) the effect of risk on contractor bid markups; and (2) how contractors measure or compensate for project risk. They found that although risk apportionment influences bidding price by about 3% of the total cost of a project, most contractors had no specific way of measuring or quantifying risk. Modern estimating textbooks, however, represent the contractor contingency generally as a fixed percentage of around 5-10% of direct cost. None of the 12 small-to-medium sized contractors in USA interviewed by [17] had any knowledge of the mathematical models used to formulate contingency, and they did not have any formalized technique they used for estimating contingency. Contractors normally apportion risk by applying a fixed percentage figure to the base costs of a project. But this approach can hardly be considered as logical and effective as every construction project is bespoke. Such practice can propel a construction company to grave losses, as sensible apportionment of risk should correspond to the extent uncertainty in a project. Similar studies of contractors in the UK and USA by [1] and [3] respectively corroborate the low take-up of analytical risk models in practice, including reasons why contractors sparsely patronize them. The former studies expose the need for systematic approaches to contractors' risk assessment whilst the latter studies advocate for methodologies that are more realistic that contractors can incorporate into the bidding process.

Seminal works in this include a classical construction risk management system (CRMS) introduced in [2] to serve as logical substitute to the traditional unsystematic approach used by contractors. Several analytical risk models have since proliferated but for reasons well defined in [1] and [3]; contractors hardly use them in practice. Key contributions in this include a fuzzy set construction risk-pricing algorithm proposed in [14] and another fuzzy set model introduced in [18] to help contractors in project risks contingency allocation. Contemporary risk models have shifted paradigm from classicalism towards conceptualism. Classical risk models rely on knowledge domains such as probability theory and Monte Carlo simulation. Theories such as fuzzy sets and neural networks underline the formulation of conceptual risk models. The main argument engineering this paradigm shift is that adequate historic data that is required for construction risk analyses can be obtained in linguistic but not numeric form. Contractors are often reluctant to record data as the project progresses, which often leads to inadequate historical objective records. The availability of adequate data to enable the confident pricing of work can therefore be obtained in linguistic form from experts and persons with the relevant knowledge [2].

Theoretically, this drift may present a way forward but, in practice, contractors may be unfamiliar with these techniques. Time may also be unavailable to apply these sophisticated models during the process of bid preparation. The need is for practical and simplified (easy-to-apply) models that mimic the traditional use of intuitive judgement and experience by contractors when dealing with risk. There may also be the need to depart from quantifying only the positive risks that increase contingency. [17] found that in times of high competition, contractors do not include contingency in their bids. The identification of risk ought to have a serious influence on a contractor's pricing strategy but other factors also influence pricing levels. Contractors are normally desirous of winning work to sustain labour and business costs. Hence, formal risk models ought to also take account of the negative risks (opportunities) in a project when evaluating contingency in order to enhance competitiveness. Unlike the contingency item in the client's budget, contractor contingency is not a line item in the tender as most formal risk models assume. Contractors tend to spread the risk over individual cost items in a tender. If contractors would take up risk models in practice, then it is proposed that they are mimicked after what happens in practice, to make them user friendly. Construction contractors may be unable to analytically explain the science or psychology of their risk response mechanisms. However, years of contracting experience provide them an intuitive understanding of the construction industry economics that they apply to adjust price and resources based on perceived risks and opportunities. We can witness such empirical knowledge, and formalize it to improve the practice of arbitrary contingency allocation.

Contractors are less likely to win a contract if contingency is set too high. Contingency set too low could result in significant financial losses [17]. Risk analysis in bid preparation helps not only to evaluate uncertainty about the tasks required under the contract, but also to formulate bids that give an appropriate balance between the risk of not getting the contract and the risk associated with potential profit and losses if the contract is obtained [5]. This complex background sets the context within which the relatively simple model proposed here has been developed to help to bridge the extant gap between the theory and practice of risk assessment in construction industry.

3. Risk and risks

Construction risks are often perceived as events that influence the traditional project triple constraint objectives of time, cost, and performance (including quality) within the period of construction. Three characteristics can be used to describe a risk event: (1) a loss associated with the event, often called the risk impact; (2) the likelihood that the event will occur, with risk probability often measured with a number between 0 (impossible) and 1 (certain); and (3) the degree to which the project team can change the outcome, either by mitigating the risk's causes before they occur or by controlling for the risk's effects afterwards [15]. This characterization provides an example of how the project management risk literature has focused mainly on the positive risks that increase contingency. There are several definitions of project management risk. Most definitions have, however, been consistently focused on deviation from expected outcomes. This proliferation of risk definitions may be centred on the common synonymisation of risk with uncertainty. Quite often, experts have used knowability and unknowability of the outcome of an event to distinguish risk from uncertainty. Forces (risks) that contribute to variations in return constitute elements of risk. The terms 'risk' and 'risks' are frequently used interchangeably in the literature. [2] define risk as the exposure to the chances of occurrences of events adversely or favourably affecting project objectives as a consequence of uncertainty. [11] also states that risk is essentially the consequence of uncertainty. Generally, risk relates to possibility that realized returns will fall short of the returns that were expected [9]. In specific relation to construction contractors, [19] view risk as: 'the possible loss resulting from the difference between what was anticipated and what finally happened'. This definition also falls short of acknowledging the positive side to risk (opportunity). In summary, risk can be described as the deviation of project outturn from the outcome that was expected. Risks can be considered as the force(s) that caused the deviation.

Portfolio theory and capital market theory stipulate that the total risk is comprised of systematic risk and unsystematic risk [9]. Project management risk is, however, divided into internal risk and external risk [18]. But the categorisation terminologies have similar meanings. Systematic or external risks affect all organisations and are prevalent in the external environment of a project and are relatively uncontrollable. Unsystematic or internal risks are relatively more controllable organisation specific and they relate to the management of internal resources. Internal risks can further be grouped under local and global risks [18]. Local risks are specific to individual work packages of a project and cover uncertainties due to labour, plant, materials and subcontractor resources. Global risks are common to the entire project, and relate mainly to performance, contractual, location, and financial aspects of a project. The relatively non-controllable external risks are prevalent in the external environment of a project, and constitute those due to inflation, currency exchange rate fluctuations, technology change, major client induced changes, politics, and major accidents or disasters.

One measure of a risk is evaluated by multiplying the two parameters that define the concept; its probability and its impact. However, combining or comparing risks according to this multiplied product without extra consideration for the different effects the risks may have on a project can be misleading [22]. An unlikely high-impact risk and likely low-impact risk may be presented as the same, whilst their effects get hidden in the product. To help account for the two-dimensionality of project risk, research efforts such as probability impact grids (PIGs) have been proposed. But the inequality in comparing and combining risks according to the fundamental R=P∗I theory remains unresolved in the project risk analysis and management (PRAM) literature. A possible solution to the fallacy of using the fundamental theory in analytical risk models is the development of empirical models.

4. Risk modelling

There is a continuum of methods to model risks across project management, construction, finance, engineering, and decision science disciplines. Classical methods such as probability theory and conceptual methods such as fuzzy set theory and neural networks are, however, commonly used to model risks across project management and construction. Risk modelling methods vary in their relative reliance on historical data versus expert input. Each has advantages (and disadvantages) over the others and requires varying skills. Therefore, a particular method should be chosen to match the facts and circumstances. There are many ways to classify risk-modelling methods. But generally, they can be grouped based on the extent to which they rely on historical data versus expert input [16].

Specifically, risk-modelling methods can be categorized as: (1) methods based on statistical analysis of historical data; (2) methods based on expert input; and (3) methods based on a combination of data and expert input. Methods under group (1) above include stochastic differential equations (SDEs), extreme value theory to model the tail of a probability distribution, and regression over variables that affect risk. These methods can appropriately be used when there is adequate historical data. Unfortunately, most construction organisations do not have adequate historical data on projects. Where there is little or no objective data, decision scientists have had to rely almost exclusively on methods based on expert input to quantify risks. These include the use of methods such as: Delphi --- to elicit information from a group of experts; decision trees --- which lay out decision points and resulting discrete uncertain outcomes; and influence diagrams --- which also map out cause-effect relationships. Over time, these methods have been refined to minimize the pitfalls and biases arising from estimating subjective probabilities, thereby increasing the reliability of these approaches. Methods in the third category rely on a combination of historical data, to the extent it's available, and expert input as needed to fill data gaps. They include, for example: fuzzy logic --- which uses linguistic variables and rules based on expert input; neural networks --- which rely on artificial intelligence; system dynamics simulation --- which uses non-linear system maps to represent the causal dynamics of a system; and Bayesian Belief Networks (BBN) --- which rely on a network of cause-effect relationships quantified using conditional probabilities. Suitability of a method will therefore depend on an analyst’s objectives and the amount of data available.

Over the years, these modelling methods have been used to formulate formal and analytical risk models that can be used across the construction industry to assess risks. [2] employed the influence diagramming technique and Monte Carlo simulation to develop a risk model to serve as a logical substitute to the traditional unsystematic approach used by most contractors to deal with risk. [6] used a risk analysis software to develop a classical risk assessment methodology for underground construction projects. [20] utilized Fault Tree Analysis (FTA) to develop a risk analysis method for building projects. [8] used the logistic regression method to model a technique for assessing the risk associated with tendering for a building project in China. [14] employed fuzzy set theory to develop a construction risk pricing algorithm. [18] also used fuzzy set theory to model a technique to help contractors in their project risks contingency allocation. Several other risk models have proliferated. But the low take-up of this proliferation of models in practice indicates that introducing more models correspondingly would not necessarily help. The need is for models formulated on a better understanding of how contractors arrive at a price, and how that price is influenced by the apportionment of risk. This question was the starting point for an ongoing ethnographic investigation into how contractors respond to risks.

5. Contractor contingency

Little attention has been focused on a precise definition and evaluation mechanism for project risk specifically related to contractors. The term contingency is generally used to describe the allowance included in project estimates to cover risks, uncertainties, and inaccuracies [12]. Many analytical techniques for determining contingency have abounded but in practice, estimators commonly apportion contingency by adding a fixed percentage of the base costs of a project to the most likely estimate of the final cost of the works. The decisions are influenced mainly by the estimator's perception of project risks, and management's view of the future and their desire to avoid an overrun situation based on knowledge from past experience [18]. This practice may be misleading as the rational apportionment of contingency in price should correspond to the extent of risks and uncertainties in each unique construction project managed by a unique management and construction team. Justifying this using an example from the client perspective, the Hong Kong Government formulated the Estimating using Risk Analysis (ERA) technique in 1993 for determination of the contingency allowance in capital cost estimates of all Public works projects in a more rational way. This followed concern over how the arbitrary allocation of contingency sometimes created scary initial project estimates that led to abandonment of some projects.

Clients have relatively greater liberty in apportioning contingency (usually a line item in the estimate) since the allowance is normally not considered part of the actual project cost. But contractors do not have this fortune. The amount of contingency they can apportion in the final bidding price is stingily regulated by a competitive strategy used by most clients for awarding work. Even here, contractors often have to commit to a price long before actual construction of a project begins. Effective forecasting of risks is therefore a key requirement for profitable contracting. The bottom line of contracting; like all other businesses, is profit. Therefore, prudent risk estimation ought to have a serious influence on estimating and pricing policies of contractors. [19] emphasizes that there is a hidden premium in every contractor's tender for risk. But [17], through interview studies of 12 contractors in the USA, found that in times when competition is high, contractors do not include contingency in their estimates in order to win work. Currently, an ongoing study at the Department of Building Technology at Kwame Nkrumah University of Science and Technology in Ghana seeks to investigate the influence of risk apportionment on bidding prices of contractors to help address the low take-up, in practice, of formal risk models for determining contingency. Contrary to the 0% finding of [17], [13] estimate the price of risk in construction tenders around 3% of the total project cost from experimental studies of 30 contractors in the USA. Besides variable measurement related reasons, growing competition in the construction industry may be a reason behind the significant drop in value of contractor contingency in bids. Despite these numerous unanswered questions in the area of contractor contingency, very few studies address how it can be evaluated, considering also the other factors that affect price.

As a starting point, [17] define contractor contingency as: 'a contractor's estimated value of the extraordinary risks that will be encountered in a project'. Extraordinary project risks are those not covered by bonds, insurance, or contractual clauses [18]. Contractors usually have to self-insure these risks by apportioning contingencies in the tender. However, the process of valuing appropriate contingencies is complex and poorly understood in practice. Contingency is significantly a function of factors as: workload; contract size; project complexity; number of bidders; owner's reputation; bidder mentality; clarity of contract documents; and time frame for bidding [17]. Mode of arriving at the bidding price and the mode of awarding work may also influence contingency. [9] define risk as the possibility that realized returns will be less than the returns that were expected. Risk relates to profitability [1]. We can therefore define contingency, in the context of contractors, as an allowance on top of the expected (anticipated) return to cover the possibility or chance that realized (actual) returns will be less than the return that was expected.

6. Contingency approximation model (CAM)

Contractors are repulsive to sophisticated risk models that omit a market competition factor [17]; and require unfamiliar mathematics, unwarranted time, and too much data that make them difficult to apply [1]; [3]. They need simple risk models that can be easily applied to obtain approximate results to guide the decisions on the pricing levels that are appropriate to their circumstances. Risk assessment ought to have a serious influence on a contractor's pricing strategy but there are other factors that also affect price. Ultimately, risk apportionment levels may be determined by the market and not results generated by risk models.

The model presented here is intended to provide contractors with a simple way of approximating local contingency for individual cost items when building up prices. Five germane contributions in the literature have seminally informed this work: risk analysis and evaluation process framework in [2]; two-dimensionality of project risk that gets hidden when risks are evaluated according to the fundamental theory that one measure of risk equals its probability times its impact [22]; the concept that risk is essentially the consequence of uncertainty [11]; Hierarchical risk breakdown structure in [18]; and the statistical measure of variability of return around an expected value as a quantitative description of risk [9].

6.1 A model for approximating contingency allowance

$$\text{The price of risk (C)} = \text{BE} * \text{RE} \qquad \text{Eqn. (1)}$$

where: C = contingency; BE = base estimate; and RE = risk exposure.

Similar to the unsystematic use of fixed percentages of direct cost estimates by contractors to value arbitrary allowances for risk, equation (1) states that: the price of risk or contingency (*C*) is a function of the base estimate of a project (or work item) -- *BE*; and a risk factor that corresponds to the estimated value of a contractor's exposure to identified project risks -- *RE*. Normally, a contractor will routinely have calculated parameter *BE* from what can theoretically be described as a risk-free estimate of the direct costs of resources (plant, labour, and material) plus a charge for overheads and profit. The task for which the model is useful is the determination of parameter *RE* i.e. the modelling of uncertainty about the predicted base costs of a project. The contingency evaluation mechanism here is modelled after the three-step risk analysis and evaluation process framework in [2]. The specific steps are: (i) data collection; (ii) modelling of uncertainty; and (iii) evaluation of potential impact of risk. This work is focused on how contractors can practically achieve steps (ii) and (iii) in order to build up an appropriate price for risk (C).

$$\text{BE} = \text{DC (plant, labour, materials)} + \text{OH} + \text{RR} \qquad \text{Eqn. (2)}$$

where DC = direct costs of resources (plant, labour, and material); OH = overheads charge; and RR = required return.

6.1.1 Modelling of uncertainty

The process of modelling of uncertainty involves the assessment of probability distribution, and the assessment of potential consequences. Eqn. (2) can help contractors to analyse their exposure to project risks (*RE*) using both objective and subjective input data.

$$RE \equiv \pm \frac{\sum_{i=1}^{n} P * I}{y_{\infty}} \qquad \text{Eqn. (3)}$$

where RE = risk exposure, P = risk probability, I = risk impact, and y_{∞} *= normalization factor.* $0 < P, I < 1$.

It is standard project management practice to estimate separately both probability and impact. Normalizing *RE* by averaging the value of total risk is fallacious even though many do it [7]. The impacts must all be on the same scale so that they can be compared. When two or more risks are estimated as P∗I, the resultant product may present them as the same. However, their effects on a project may differ. The need is for an evaluation mechanism that takes additional account of the nature of impact a risk event will have on a project.

An effective evaluation mechanism for project risk should address its two-dimensionality [22]. This requires a two-stage evaluation process. The first-stage should answer the question: will the risk event have a positive or negative impact on the project on its occurrence? This is the R=P∗I stage where the answer will help to designate the risk as a positive or negative spread about the predicted costs. Since all positive or negative risks may not be equal, the natural question that extends the argument into a second-stage evaluation process is: what nature of positive or negative impact will the event have on the project? Will it be high, medium or low? So for each risk, an estimator will be required to answer whether the event creates positive or negative risk (R=P∗I), and then analyse the kind of impact (E) the risk will create.

In a qualitative sense, this can be expressed as: *will the risk event have positive or negative impact on the project when it occurs (R=P∗I), and (∗) what kind of positive or negative impact (E) will it have?* In a mathematical sense, this can be stated as:

$$Risk = probability * impact * effect\,(PIE) \qquad \text{Eqn. (4)}$$

Tests of equation (4) against the conditions set out in [22] validate the usefulness of this extension for comparing and combining non-singular risk events. Hence:

$$RE \equiv \pm \frac{\sum_{i=1}^{n} P * I * E}{y_{\infty}} \qquad \text{Eqn. (5)}$$

where RE = risk exposure, P = risk probability, I = risk impact, E = weighting factor = nature of effect risk will have on the project, y_{∞} *= normalization factor, and 0< P, I, E<1.*

Risk probability (*P*) can be determined in various ways. But for simplicity sake, risk will be assumed to be synonymous with uncertainty in this study. Risk probability will thus equal the uncertainty of performance. Uncertainty is simply a lack of certainty [21]. Hence:

$$P \approx 1 - CP \qquad \text{Eqn. (6)}$$

where P = risk probability, and CP = certainty of performance.

There is, however, a margin of inaccuracy in this because even if one is absolutely certain, there are errors associated with the degree of certainty, and so the risk probability can never actually be zero. Determination of risk impact (*I*) and nature of the impact (*E*) will solely be based on subjective assessment and experience of the analyst. Here, an analyst will be required to use available historical data, intuitive judgement, and their previous experience to express subjective probabilities about certainties of performance, and likely consequences of risk events. The normalization factor;

$$y_{\infty} = N_r \qquad \text{Eqn. (7)}$$

where N_r *= number of risks analyzed*

6.1.2 Evaluation of potential impact of risk

The contingency approximation model (CAM) in equation (1) is intended to provide a system for linking risk exposure (*RE*) to the expected values of construction (*BE*). The model can help contractors to estimate the needed contingency to cover risk in monetary terms. This allowance should cover to the possibility / chance of actual costs deviating from the predicted costs of a project.

The contingency allowance can quantitatively be approximated as a measure of variability about expected project costs / profit. If an analyst is absolutely certain (100%) about the consequence of each risk event, the project can theoretically be assumed to pose zero risk (0%). The value of *RE* represents the maximum aggregate dispersion of risk about the predicted cost of a project for which the contractor is not certain about performance. If a 0.046 *RE* resulted from the analysis (as illustrated in appendix 1), needed contingency will be approximately 4.6% of the base estimate -- *BE*. Thus:

$$\text{Price of risk (C)} = \text{BE} * \text{RE} \qquad \text{Eqn. (1)}$$

where: C = contingency; BE = base estimate; and RE = risk exposure.

7. Discussion

Four issues are important to discuss. First, how can one reduce contingency levels to increase competitiveness? Second, is the model useful? Third, what is different about this approach? Four, how accurate is forecasts of the model? Two parameters define contingency (*C*) -- *BE* and *RE*. Managers may not have much influence over *BE* since it responds directly to the market. However, analysts can minimize their risk exposure (*RE*) by increasing their degree of confidence about risk events through additional information. This will invariably lead to lesser contingency levels. But a cost-benefit analysis of obtaining additional information is needed, as well as whether additional information may not actually increase contingency. The CAM mimics what happens in practice scientifically. But the difference is that whilst most contractors apportion risk using arbitrary flat percentages, this technique helps to determine the percentage logically based on the extent of uncertainties in a project. Since contractor contingency is not a line item as most analytical models assume, it provides a handy tool that contractors can use to estimate contingencies locally as is done in practice. The conservative use of intuitive judgement and previous experience by contractors is captured into the model. Results of analyses would indicate areas of high exposure to the project risks. This permits analysts to go back to provide specific responses. The CAM is practical and user friendly. The model does not entail the usual unnecessarily complex mathematics that contractors are unfamiliar with; it is intelligently simple, which is the key to expediency in practice. Further work to validate the model is ongoing, as risk may not occur in the whole region of exposure.

8. Conclusion

The intention of the CAM is to help contractors analyse their exposure to project risks, and evaluate an appropriate contingency in monetary terms during the bid pricing process. The model is useful despite unnecessary elegance in its math as has become the norm.

Normalizing *RE* through simple averaging is an evident limitation but contractors have a critical need for simplicity in order to respond positively to formal risk models. The anticipation of this work has been to contribute a solution towards the low take-up of risk models in practice by contractors, and provide them a logical substitute for overcoming the problem of arbitrary allocation of contingency. Further work is ongoing to refine and validate the model for better approximation of the contingency allowance and determination of minimum values for break-even. Nonetheless, contractors can certainly benefit from the CAM as it stands.

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10. Appendix: hypothetical illustration

Having specified a base estimate, charge for overheads, and required return for a project, a contractor may wish to determine an appropriate contingency allowance to cover the following five risks: labour productivity (R_1); workforce strikes (R_2); inclement weather (R_3); materials availability (R_4); and price fluctuations (R_5).

To model uncertainty of these risks about predicted costs of construction, an analyst will be required to subjectively express degrees of certainty about the nature of the risk / opportunity events based on all information available at the time of pricing. Risk probability; $P(R)$ thus becomes a measure of the alternate region of uncertainty i.e. one minus certainty of performance, measured on a scale of zero to one.

For risk event number one (R_1); labour productivity, an analyst (probably the estimator) has to express a degree of confidence about the risk event to begin the analysis. If a contractor has known the workers and has an approximate idea of their output, then we can assume, although this ideal kind of situation hardly exists, that no risk is posed since risk is essentially the consequence of uncertainty. This reduces the situation to a purely management problem. All an analyst has to do is to adjust rates in accordance with known levels of output so that risk is not incurred. Conversely, if the job was to be done at a place where a contractor has no previous experience with local labour, some level of uncertainty will surround the building up of prices for labour items. An analyst can therefore subjectively express, for example, seven (*7*) chances in ten (*10*) degree of certainty about labour productivity on the project. The alternate three (*3*) chances in ten (*10*) spread is the measure of risk exposure (*RE*) about which a contractor is uncertain of performance. Theoretically, this represents the maximum region of risk occurrence. Thus, 'likelihood' can be recast into 'probability' by expressing P (R_1) as *0.3*. We can apply the same logic to analyse R_2; R_3; R_4; *and* R_5 and estimate their probabilities as, for example: $P(R_2) = (0.2)$; $P(R_3) = (0.3)$; $P(R_4) = (0.1)$; and $P(R_5) = (0.4)$.

From these facile measures of uncertainty, one analyst could have nominally averaged total risk i.e. $(0.3 + 0.2 + 0.3 + 0.1 + 0.4)/5 = 0.26$. This will lead to the assumption of a *0.26* risk exposure for the project. Although this may provide an estimate on the degree of project risk, such nominal resolution of uncertainty constitutes an assumption that all risks are significantly equal. This is erroneous.

A possible way to minimizing such error is to attempt leveling the risks by weighting each event by what we know of their impact / effect. Assuming that the most likely consequences of R_1; R_2; R_3; R_4; and R_5 on price are: *0.3; 0.5; 0.6; 0.2; and -0.4* respectively based on experience, factoring the risk analysis equation would show that the earlier risk value of *0.26* will no longer result. The risk exposure (or value) will now become: $[(0.3*0.3) + (0.2*0.5) + (0.3*0.6) + (0.1*0.2) + (0.4*-0.4)]/5 = (0.23/5)$ (0.046). As can be seen, R_5 is forecasted as an opportunity event; in anticipation of some price reduction in future. Instead of a nominal comparison or combination of the events, the error margin is reduced from *0.26* to *0.046* by weighting the risks with what we know of their impact. With parameter *RE* determined, this factor should be multiplied with the predicted base costs to shield against potential losses (or gain).

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