University of Reading

The Implication Of BIM Use on Communication Channels in Design Processes for Saudi Architectural Engineering (AE) Firms

Thesis Submitted for Degree of Doctor of Philosophy (Ph.D.)

School of The Built Environment

Aljwhara Abdullah Alnaser

Sep 2017

DECLARATION

I confirm that is my own work and the use of other sources has been properly and fully acknowledged.

Name: Aljwhara A. Alnaser

Date: 28-9-2017

Acknowledgments

When I began to write this thesis, I hesitated, wondering for whom I should write and where to begin. I found that tears came before my pen. While it may seem that this study is the result of one person's efforts, indeed it is not. I want to take this opportunity to thank all of the people who supported me in completing this journey.

First, this thesis would not exist without the patience and tolerance of my daughters, **Tala and Joanna**. They provided me with strength and patience without which I would be unable to complete this journey, which began on the 9th of January 2013. I heard big words from little children who were suffering in silence about missing their mum:

"Mama, never give up…", "Mama, we are fine, don't worry…", "Keep going, Mama, we are proud of you…."

Indeed, I appreciate them and all children around the world who can overcome their feelings and push their parents to become better. I know this was tough for my daughters, and I cannot imagine how they did it. However, I am proud of you, my darlings, and now with a loud voice I can say: "We have overcome, and we were stronger than all of our circumstances. We did it."

I would also like to express my deepest thanks to my adviser, **Prof. Chris Harty**, for his useful comments, ongoing support and his enthusiasm for my research. I was lucky to have a supervisor who cared a lot about my work and always promptly responded to my questions. I am grateful for his supervision style and his willingness to sometimes let my four-year-old daughter Loulia join our meetings. I appreciate Chris as both a supervisor and a human being.

I would like to thank my local sponsor, the **Royal Commission of Jubail and Yanbu,** for giving me this opportunity to study abroad. Also, I appreciate the **Saudi Bureau in London** for their care, supervision, and use of their facilities. I'd also like to thank my Master's supervisor **Prof. Abdulsalam Ali Al-Sudairi**, the Dean of College of Architecture and Planning at Imam Abdulrahman Bin Faisal University (IAU), for his suggestion to continue my studies at the University of Reading.

Importantly, a special mention for my parents, **Abdullah and Sheikha**, for their effort, patience and faith in my abilities. I thank them for taking care of my little girl Loulia for two years as I drew up my research plan. Thank you, also, for visiting me from time to time to look after Loulia during a busy period of searching. Thank you, father, for your belief that there is no

difference between men and women in education, that true education is absolute for those who wish to pursue it, and that nothing is above human desire. Thank you for helping me to make my dream a reality. Deepest thanks also to **my brothers and sisters** for their continued support and encouragement.

I also want to thank many others who have accompanied me on different stages of this journey:

My friends and colleagues inside and outside the University for their care, help, and advice.

Senior Postgraduate Research Administrator **Katie** Saxelby-Smith, who provided me with constant support.

To all of you, thanks for all the encouragement.

Aljwhara A. Alnaser
19-09-2017

Abstract

This research explores the implications of implementing building information modelling (BIM) on existing communication channels used in the design processes for professionals at architecture, engineering (AE) firms in the Kingdom of Saudi Arabia. Although considerable research on communication channels exists in terms of their effectiveness in collaborative environments, such as face to face meetings versus computer-mediated communication (CMC) technologies, to date relatively few studies have investigated the effect of implementing BIM on existing communication channel mechanisms at Saudi AE firms.

In doing this research, three different concepts were mobilised in order to understand the dynamic processes of communication among diverse AE professionals in general, and within BIM collaborative environments in particular. Importantly, three different literatures: communication, team, and collaboration were considered as the main pillars of this study. In addition, this study reviewed theoretical communication process models (from linear to interaction processes), team theory, and cross-profession collaboration theory. Based on this review, 38 distinct factors were selected based on their impact on dynamic communication, team, and collaboration processes. These factors were grouped into three themes: 1) collaborative team characteristics; 2) leadership; and 3) methodology of information exchange. These themes were then used to develop an analytical framework to explore the implications and effects of BIM technology on the communication channels used by various professionals. Significantly, some overlap between these 38 factors was identified both within and across these themes, which subsequently assisted in developing the empirical research questions and in exploring further factors and their influence on communication channels during the qualitative data analysis process.

To prepare for this research, a pilot study was first conducted on three Saudi AE organisations and one individual from the Saudi Ministry of Health. Based on the outcomes of this pilot study, a broader case study was then conducted on a leading Saudi AE firm that uses BIM. This study collected qualitative data through semi-structured interviews with 22 professionals in various departments at one prominent Saudi firm.

The case study findings revealed that adopting BIM technology at this firm resulted in changes in the mechanisms used for communication channels among various professionals. Specifically, BIM adoption changed communication patterns (e.g. from formal to informal, and vice versa) and subsequently the type of communication channels used. As a result, one

to one or group meetings paired with the use of hand sketches during such meetings emerged as the most preferred means of communication for these BIM users. In addition, when compared to the case study firm's former CAD-based system, such changes were accompanied by reduced time spent on communication processes themselves and decreased dependence on previous communication channels (e.g. FTF meetings and email). However, no conclusive evidence emerged as to whether adopting BIM technology either reduced or increased the need for verbal communication at this firm. Importantly, this study concluded that adopting BIM changed the communication channels used at the firm, and that these changes were dynamic.

Notably, the study results suggest that this phenomenon was a result of influences that were grouped into five themes: the communication protocols applied, the impact of rumours, the level of leadership, resistance to change, and the technical features of BIM technology. It is worth noting that of these five themes, four relate to the conditions and characteristics of the organisation, and the fifth concerns the characteristics of the BIM technology itself and the benefits it affords in improving information exchange processes.

Given these findings, one could conclude that changes occurred in communication channels after the firm adopted BIM, and that these changes were due to the technical features of the technology and the organisational environment. However, the magnitude of the impact of the firm's organisational environment had a major impact on these changes. With respect to contribution to knowledge, this study also found that the spread of rumours within or across the firm played a significant role in changing communication channels, either due to the process of verifying or responding to these rumours.

list of contents

List of figures

List of tables

Chapter 1

Introduction

Chapter 1.

1.1 Introduction

There is an ongoing debate in academa and industry about the nature of BIM. A number of practitioners and researchers have defined the philosophy of BIM in different ways. For some, BIM is *"data sharing, and not only data exchange"* (Nour 2012: 1); for others, BIM is an integrated model (Sebastian 2011), simply *"a software application"* (Aranda-Mena et al. 2009: 420), or shared digital representations and language allowing interoperability (McGraw-Hill 2008). Because these definitions differ, they have generated much discussion about if this diversity affects the way in which design participants exchange information. In addition, how might using BIM change existing communication patterns among design team participants? Does it enhance the tendency of these actors to communicate, or generate gaps and make them isolated? And in terms of this study, when firms use BIM, what happens to existing communication channels, and why?

These are important questions, particularly as one of the core features of BIM is 'interoperability' (Succar 2009), which IEEE (1990: 114) defined as *"the ability of two or more systems or components to exchange information and to use the information that has been exchanged."* This process of information exchange reflects two pillars of BIM work: communication and collaboration (Azhar et al. 2012). Furthermore, the literature suggests that with respect to the role of collaborative teams, there is some consensus that these teams can serve as a third pillar. In addition, a review of the literature on BIM also shows a general consensus about the main challenges of implementing innovations (i.e. BIM), and for information exchange in particular. These common challenges include lack of sufficient training for team members and resistance to change (see Azhar et al. 2007; 2012; Dossick and Neff 2011; Harty 2008; Homayouni et al. 2010). However, while one cornerstone of BIM is the communication process, which enables stakeholders to collaborate and deliver information (Xue et al. 2012), according to the literature some shortcomings remain in communication processes for BIM projects.

At the domestic level, as of 2010 few mid- to large-sized Saudi firms had implemented BIM in the design process. This fact has motivated Saudi researchers and developers to evaluate the challenges and benefits of implementing BIM in the Saudi construction sector (Al Soliman 2012; Alshalhoob 2012). In light of this, many Saudi studies have concluded that although

adoption of BIM typically results in a decrease in design errors, there remains a lack of communication processes and shared understanding among design participants (Al Soliman 2012; Alshalhoob 2012). This has, in turn, led to increases in not only the number of clash detection meetings for firms but also in change orders. Furthermore, a review of 22 Saudi studies suggests that insufficient communication is most likely the primary challenge that design offices face. Moreover, such studies suggest the importance of not only implementing collaborative design environments using BIM, but also improving communication patterns between parties. However, the aforementioned Saudi studies concluded that a lack of communication remains among design teams for firms that use BIM technology, and that CAD is still the preferred format for clients in Saudi Arabia.

Additionally, to date relatively little is known about the consequences of implementing collaborative approaches such as BIM on the communication channels used among design team members. In this respect, this study will identify 'what' happened to the existing communication channels at the case study firm, if and how they have changed, and 'why.' In this study, communication channel refers to *"the medium of communication: the material through which the content is sent"* (Dainty et al. 2006:112). With increasing growth in network speeds, information communication technology (ICT) has afforded opportunities for professionals to communicate in various ways, such as texting, chatting and visual communication (Hatem et al. 2012). In addition, in collaborative design environments, communication has grown more complex and professionals have many communication channels to choose from (Gabriel and Maher 2002; Eckert et al. 2005). In fact, Gabriel and Maher (2002) proposed this diversity of communication channels as their main criterion for the success of collaborative communication. In general, many studies have focused on the influential factors behind either changes in communication channels in particular, or on the selection of those channels, which may differ from one work environment to another. Despite this distinction of context, some researchers have achieved consensus on some of these influential factors, such as individual preference (Watson-Manheim and Belanger 2002; Gabriel and Maher 2002), organizational culture (Homayouni et al. 2010; Watson-Manheim and Belanger 2002) and physical environment (Dainty et al. 2006; Watson-Manheim and Belanger 2002). Interestingly, many scholars' views on communication and collaboration (e.g. Ebrahim et al. 2009) also suggest that team members are the primary unit in the communication and collaboration process, who impacts and is influenced by the surrounding environment. In addition, within the design process context, it is fundamental to understand the core role team members play as senders and receivers within communication processes.

The aim of this thesis is to explore the implications of implementing BIM on communication channels used in the design process by various professionals. To achieve this aim, this research draws on three theoretical approaches. The first is communication theory (i.e. Shannon and Weaver (1949): linear model (one-way process), Defleur communication model: interactive model (two-way process):, and Schramm's communication model (i.e. field of experience and encoding knowledge skills). The second is team theory (Brennen et al. 2007), and the third is cross-profession collaboration theory (Amabile et al. 2001). Along with this, three different sets of literature: communication, teamwork, and collaboration were also reviewed in parallel

For doing the research for this thesis, selected potential factors were extracted from three main sets of literature and the theories listed above. These factors were chosen terms of their influence on the identified main areas and the relevant theory, and subsequently for their potential influence on changing the communication channels used. As a consequence, this study identified 38 potential influential factors, which were grouped into three major categories (i.e. themes): the methodology of information exchange, collaborative team characteristics, and leadership. Importantly, some overlap emerged in terms of the influence of these identified factors either within each theme or across these three themes, which assisted in crafting the research questions for the pilot study. To address the aim of this study, a case study strategy was applied and data were gathered from 22 participant interviews from one AE Saudi firm that has adopted BIM technology. Thematic analysis was employed to analyse the interviews data. Conducting the pilot study was also an initial step in refining the research questions, identifying suitable cases, and testing the data collection approach for the main study.

1.2 Research aim and objectives

The main aim of this research is to *"explore the implications of BIM execution on existing communication channels used in the design process by various professionals*." In order to meet this aim, the research objectives are**:**

1. Review the literature to identify a range of potential factors that might influence communication channels used within BIM-related work environments, and to develop an analytical framework to use in the empirical work.
2. Conduct case study research to explore the effect of BIM implementation on communication channels, and why these effects occur.
3. Analyse collected data by drawing on the analytical framework developed from Objective one to inform and explore influential factors and effects on communication channels.

Table 1-1: Evolution of research objectives

Initial Research Questions	Interim Research objectives	Final Research objectives	Achieved in
1. To examine the extent to which BIM affects communication patterns among design teams, and subsequently their performance and results. 2. In addition, what are some implementation strategies for successful collaboration in the face of barriers and challenges in professional practice? 3. Consequently, does BIM, as a collaborative process, change existing communication methods? 4. Furthermore, does using BIM enhance communication between actors, or does it generate gaps and make them isolated? 5. Additionally, based on the expectation that implementing BIM can reduce costs up to 40% (Sebastian, 2011), does this refer to the capability of BIM to visualise projects, or its communication capabilities? 6. Finally, do project teams use BIM more for visualisation or communication?	1. To understand how the communication process operates	1. Review the literature to identify a range of potential factors that might influence the communication channels used within BIM-related work environments, and to develop an analytical framework to use in the empirical work.	**Ch 2**
	2. To identify factors that influence changes in communication channels used	2. Conduct case study research to explore the effect of BIM implementation on communication channels, and why these effects occur.	**Ch 3**
	3. To identify the communication channels enabled by BIM tools	3. Analyse collected data by drawing on the analytical framework developed from Objective one to inform and explore influential factors and effects on communication channels.	**Ch 5,6**

1.3 Thesis structure

Chapter 2. Literature review

Chapter 2 presents a detailed review of the literature and relevant theories that form the core of this thesis: communication, team, and collaboration. This chapter consists of three main sections and sub-sections.

The first section presents the challenges faced by the Saudi construction industry and its design processes by reviewing 22 domestic studies. This review concludes that the lack of communication between project participants remains one of the main challenges that BIM environment professionals face.

The second section reviews the BIM literature to explore trends and patterns in BIM research. This helped to position this PhD research in the BIM literature and to explore if current studies exist related to communication processes in general, and changes in communication channels in particular.

Following this, the third section identifies potential influential factors in changing the existing mechanism used for communication channels. This section consists two sub-sections. The first reviews three different sets of literature and applicable theories, which are mapped and organised as (1) communication processes; (2) virtual teams; and (3) collaboration. In line with the literature review, the three bodies of theory were reviewed. The first is communication theory i.e. linear model, or one-way process [Shannon and Weaver 1949], interactive model, or two-way process [Defleur communication model, and Schramm's communication model (field of experience; encoding knowledge skills)]. The second is team theory (Brennen et al. 2007). The third is collaboration theory; [Cross profession collaboration theory (Teresa M. Amabile et al. 2001)]. In addition, as it is important to uncover the main themes, the second sub-section categorises and compares the identified factors across these emergent themes. Here, this step helped in developing the analytical framework for this research and subsequently shaped the interview questions to investigate "what" happened to communication channels, and "why."

Chapter 3. Research strategy and methods

This chapter describes the research strategy and methods employed in this research in order to capture the qualitative data required to achieve the research aim. As the research

questions were presented in Chapter 2, this chapter presents the data collection methods employed in the pilot study. The pilot study was conducted to evaluate the initial interview questions and identify proper case studies appropriate for collecting the qualitative data. The chapter then outlines the data collection method used in the main case study, for which 22 professionals were interviewed. The chapter concludes with a discussion of the limitations related to the research context and the ethics guidelines that were followed in this study.

Chapter 4. The preliminary findings of the pilot study

Chapter 4 presents and discusses the preliminary findings of the pilot case study. This study was conducted to: 1) refine the interview questions for the main study; 2) identify suitable cases; and 3) test the data collection method for appropriateness. Using an email questionnaire and telephone interviews, data were collected between June and August 2015 from three medium-sized firms and a project manager from the Saudi Ministry of Health. It is worth noting that the pilot interview questions were initially drawn from the literature presented in Chapter 2 and tested during four semi-structured interviews conducted with an architect, a BIM coordinator, and project managers across four different organisations. It is also important to note that this chapter is part of a conference paper published in the CIB World Building Congress 2016, Tampere, Finland.

Chapter 5. Main case study thematic data analysis

This chapter presents the thematic analysis of the data collected from interviewees who participated in the main case study. The analytical framework presented in Chapter 2 facilitated the coding process for this textual data, which were categorised into three key themes: 1) team member characteristics; 2) leadership; 3) methodology for information exchange. Coupled with this, the chapter also lists a list of communication channels currently used with BIM technology environments at the case study firm.

Chapter 6. Discussion

This chapter discusses the research findings and interprets them with respect to the literature. The data analysis revealed five underlying themes, which are discussed in relation to their role in changing the communication channels used within BIM work environments. In addition, the analysis yielded four themes related to the characteristics and conditions of the organisational context that incubates BIM technology: 1) resistance to change; 2) the impact of rumours spread; 3) communication protocols; and 4) leadership. In addition, the technical

benefits of BIM technology also emerged as a fifth theme that influences communication channel changes.

Chapter 7. Conclusion

Chapter 7 revisits the research aim and objectives presented in Chapter 1 and summaries the research outcomes. In addition, the chapter outlines the knowledge and methodological contributions of this research. Finally, it provides suggestions for future work in the area of communication and BIM technology.

Chapter 2

Literature Review:

Communication, Virtual Team, Collaboration, and Building Information Modeling

Chapter 2. Literature Review

2.1. Introduction

This chapter reviews the relevant literature and theories by discussing recent studies with the aim to comprehensively understand the key elements that form the core of this thesis. The chapter contains three main sections and sub-sections.

The first section reviews the challenges the design process faces in the Kingdom of Saudi Arabia by examining 22 local research studies. The review findings showed insufficient communication between professionals as the main issue facing the design process in general, particularly with respect to BIM technology use.

The second section presents recent BIM-related research trends in the literature. Despite the obvious effect of insufficient communication among project participants that emerged in this literature, little attention has been paid to studying the communication processes that design professionals employ, particularly in terms of changes in the communication channels they used.

The third section outlines the analytical framework for this research and consists of two sub-sections. The first sub-section reviews research and theories from three different sets of literature, which were organised as: 1) communication processes; 2) virtual teams; and 3) collaboration. The second sub-section compares and categorises potentially influential factors and relevant theories that were found in these three bodies of literature that informed the themes of this research and subsequently guided the research interview questions.

2.2 Overview of the design process

This section presents the current state of the design process in the Kingdom of Saudi Arabia by reviewing of Saudi case studies. The research findings outline the barriers faced and the extent that communication deficiencies that have affected these challenges, particularly in the design phase. In addition, this section discusses several attempts to implement technology to improve design process performance through a review of various case studies. In addition, it presents the views of many Saudi researchers, such as Sultan (2009), who assert the fundamental importance of further improving the communication in the design phase, as

this core stage is considered a foundation upon which all later project phases depend (Al-sudairi 2008). The case study findings suggest that insufficient communication is the most common issue that emerged with respect to the design process.

2.2.1 General background of the design process in the KSA

The Saudi construction sector is one of the largest in the Middle East and is the second largest industry in Saudi Arabia (National Commercial Bank [NCB], 2010). Since 1999, many Saudi studies have addressed factors that have hindered domestic project performance. Falqi (2004) reported that the Saudi construction industry generally suffers from poor performance outcomes and that 952 (40%) of 2,379 projects in the KSA have been delayed. Similarly, Al-Kharashi and Skitmore (2009) surveyed 86 project stakeholders ranging from clients, contractors and consultants working in the Saudi construction sector in order to identify the causes of project delays. Their qualitative analysis identified the most common factors as a lack of regular meetings, a lack of clarity in drawings and specifications, and inadequate communication between the parties involved. This suggests the need to increase effective communication practices between construction project participants at all project stages. However, while most Saudi studies have focused on factors that result in project delays, broader challenges in the construction sector are often the result of communication problems (Arain et al. 2006).

With respect to the design process, Arain et al. (2006) argued that inconsistencies in design documentation represent the leading cause of construction project failures, and that they largely occur due to of deficiencies in communication at the design phase. Arain et al. (2006) and Arain and Pheng (2007) argued that this phenomenon has hindered the development of the Saudi construction sector. Furthermore, Arain et al. (2006) identified a number of specific factors, such as insufficient collaboration among contractors and designers, the inadequate detail in design drawings and a lack of coordination between participants. Arain (2008) reported additional factors that confirmed the findings of Al-Kharashi and Skitmore (2009) and Sidawi et al. (2012) in their influence on design process performance, including gaps in communication between contractors and designers, insufficient details in design documentation and a lack of coordination between parties. Additionally, other factors identified by Assaf and Al-Hejji (2006) include errors and discrepancies in design documentation; delays in producing this documentation; unclear and inadequate details; the inherent complexity of project design; inexperienced design teams; and not using engineering

design software. Further studies by Bubshait and Farooq (1999) and Assaf et al. (2001) identified aspects that can improve the quality of design firms, such as developing communication approaches and training staff to eliminate design errors that affect project performance.

The above discussion suggests that the issue of construction project delays in the KSA is a long-standing problem which created an adverse image of its construction sector. This negative image has motivated many researchers to study these challenges by focusing on the causes of these delays (e.g.,Falqi 2004; Assaf and Al-Hejji 2006; Al-Kharashi and Skitmore 2009). However, while these studies have focused on key factors that have resulted in a decline in the Saudi construction sector, few studies have investigated the design process in particular. As a result, since 2007 several studies have simulated (As-Is) design processes in order to identify the factors that might affect construction project performance by measuring to what extent these factors impact project time and cost (e.g., Al-sudairi, 2008; Mohaimeed, 2009). These researchers found that both the 'traditional design process' and ‘a general reluctance of companies and clients to use contemporary communication technologies’ constitute barriers to long-term development in the Saudi design sector. Furthermore, Mohaimeed (2009) stated that many challenges exist that limit the effectiveness of the architectural design process, the most fundamental being the technology tools used in this process. In addition, Mohaimeed (2009) found that a general lack of accurate information exchange among team members has in some cases impeded the design process by up to 67%, and that delays in delivering information among the project manager and staff hindered the design process by about 76%.

Following this, Asluliman (2012) aimed to gain a better perception of the variation in order management practices. The authors conducted an exploratory study consisting of 23 interviews (7 clients and 16 consultants) for the Saudi construction sector. The study found that a lack of using advanced communication technologies, particularly in the design phase, is one of the primary reasons for an increased rate of design changes (i.e. change orders).

In the context of remote construction projects, recent studies have reported problems related to communication and management facets of Saudi companies. For example, Sidawi and Al-Sudairi (2014) explored the extent to which employing advanced computer-based management systems (ACMS) could improve the managerial mechanisms of these companies. The researchers collected qualitative and quantitative data from 47 questionnaires and 11 semi-structured interviews with a range of professionals (i.e.

engineers, contractors, and supervisors) from three large Saudi companies and a consultant from the University of Dammam who represented the supervisor of his university's remote projects. Interestingly, despite the relatively large size of the companies involved in the study and the diversity of study participants, the results were consistent with those mentioned earlier with respect to project delays (e.g. Falqi 2004; Assaf and Al-Hejji 2006; and Al-Kharashi and Skitmore 2009) and design process challenges (e.g. Arain et al. 2006; Arain 2008; Assaf and Al-Hejji 2006; and Al-sudairi 2008). With respect to these challenges, it appears from this study that poor communication between project parties, a lack of skilled manpower and company infrastructure are some of the main factors in the success of these companies in managing their remote projects. The authors categorized the identified issues into four areas: 1) procurement and risk management; 2) cost, time, and quality management; 3) human resources; 4) IT infrastructure and communication.

In addition, completing construction projects on time and within budget remains the primary issue confronting the Saudi construction sector (see Alzara et al. 2016; Assaf and Al-Hejji 2006; and Al-Kharashi and Skitmore 2009). In this vein, Alzara et al. (2016) conducted a study that aimed to decrease project delays in the Saudi construction sector. The authors conducted case study research on a university campus located in northern Saudi Arabia that has been under construction since 2006. The results showed that campus construction was delayed by 50 to 150%, figures that are in accordance with the literature on the percentage rates of construction project delays, which can reach up to 70%. In terms of delay factors, Alzara et al. (2016) found agreement with previous domestic studies for nine factors: delays in payment to contractors; lack of experience/qualifications; contractor performance; material delivery issues; inadequacy of human resources; bidder systems; deficiencies of consultancy staff; and delays in revising and approving design documents.

In the context of Saudi residential building projects, Mahamid (2016) investigated the direct and indirect causes of dispute for these projects. The author analysed the data from 150 randomly-distributed questionnaires and found 61 causes for disputes. Notably, 29 of them were related to direct disputes, the top five of which were change orders, low quality of finished work, lack of skilled labour, delays in client payments, and unreasonable contract durations. The top indirect causes included a lack of communication between parties, cash flow issues in the construction phase, inadequate estimation practices, unsuccessful project planning and scheduling by contractors, and insufficient contractor experience. Here, it is important to note that this study advances our understanding that the existence of poor

communication between project parties can play a critical role, not only in terms of project delays (e.g. Falqi 2004; Assaf and Al-Hejji 2006; and Al-Kharashi and Skitmore 2009) and change orders (e.g. Asluliman 2012), but also for dispute issues between parties.

It is worth noting that these findings have spurred interest in the construction field to shift from detecting the causes of delays to improving design performance by exploring alternative solutions. Such solutions generally highlight the importance of technology and its essential role in communication. For instance, applying web-based project management systems (WPMS) in the Saudi context generally faces many challenges. In a study conducted on the Royal Commission of Jubail in the KSA, Sidawi and Omairi (2010) found several barriers to the implementation of information communication technologies (ICT), including staff resistance to changing their work methods and processes; relatively low levels of IT infrastructure; concerns about making significant investment without any guarantee of success; and a preference for paper-based systems. In this context, Sidawi et al. (2012) suggested the use of BIM, is one way to improve architectural project management performance and improve the rate of knowledge transfer. Using these methods, designers can interact with formal and informal communication channels such as audio and video conferencing, email, and online chat applications (Du et al. 2012). The widespread availability of these and other communication channels could lead to improvements in the design process toward more collaborative design methods (Gabriel and Maher 2002), meaning processes in which projects are delivered using the collective efforts of many designers who share ideas, expertise, resources and responsibilities (Wang et al. 2002; Chiu and Cheng-kung 2002). It is worth noting that the challenges that face the Saudi construction sector do not significantly differ from those of other sectors internationally. In fact, these challenges, which result from a number of factors, appear as common causes of construction delays in many international studies (e.g. Alaghbari et al. 2007); these are discussed in Section 2.2.2. Finally, these commonalities could present opportunities for local investors allied with experienced international organizations.

2.2.2 The status of BIM in the Kingdom of Saudi Arabia

All of these findings represent the current state of design process performance in the KSA. In response, in early 2010 two large Saudi firms (Aramco and the Royal Commission of Jubail and Yanbu) and several mid-size companies began to implement BIM in the design phase of

their construction processes. This shift has motivated Saudi researchers and developers to evaluate the benefits and drawbacks of introducing BIM in the Saudi construction sector.

However, as relatively few Saudi firms have adopted BIM processes to date, many recent studies have examined the potential challenges of the barriers to implementing BIM in the KSA (e.g. Al Soliman, 2012; Alshalhoob, 2012). In particular, Alshalhoob (2012) studied the King Fahad Hospital project in Dammam, and found that key barriers to adopting BIM into the design process at Saudi firms included a lack of communication between parties and substandard IT skills. Furthermore, while incorporating BIM for this project BIM resulted in relatively fewer errors and generally improved the quality of design documentation, a lack of communication and IT skills were evident, which was seen as leading causes for construction delays. Importantly, Alshalhoob (2012) found that this lack of communication and shared understanding among participants led to increases in the number of clash detection meetings and change orders. Moreover, this study identified the need not only to foster collaborative design processes using BIM, but also to improve communication between parties.

Similarly, Alsoliman (2012) investigated barriers that can hinder the implementation of BIM processes in the KSA. This study was based on semi-structured interviews and questionnaires with professionals from both small and large companies representing both the private and public sectors and contractors in Saudi construction industry. The results showed that notable challenges included a lack of awareness about the benefits of BIM, a lack of trained staff, and insufficient company infrastructure, all of which have hindered BIM implementation in the Saudi construction industry. In addition, Alsoliman's (2012) concluded that traditional CAD approaches remain the preferred method for producing design drawings, and that nearly 90% of Saudi firms had not yet implemented BIM.

In this regard, while a few researchers, such as Sidawi et al. (2012), have asserted that implementing BIM methods can optimize performance between parties, several Saudi studies have found considerably poor communication performance between participants in BIM environments (Alshalhoob, 2012). This and other factors have led some to conclude that the administrative approaches and design methods used in many Saudi design firms are no longer be able to deal with contemporary methods (see Sultan 2009). Moreover, Sidawi et al. (2012); Alshalhoob (2012); and Al Soliman (2012) recommended that approaches to adopting more collaborative environments in design offices using BIM applications should pay more attention to improving the communication processes among professionals. With respect to the status of BIM implementation in the KSA, it can be said that the experience of Saudi firms

with BIM remains in its early stages and is focused primarily on minimizing errors in design drawings. In addition, particular challenges that have received significant attention in the Saudi BIM literature include a lack of IT skills, general resistance to change, lack of communication between professionals, and preference factor (Alshalhoob, 2012; and Al Soliman, 2012). It can be seen also from this example that these challenges are similar to some of those identified in many international studies on BIM processes (Sebastian, 2011; Dossick and Neff, 2011; and Eadie et al., 2013).

Another example of applying BIM technology in Saudi Arabia concerns calculating the direct and indirect emissions resulting from construction projects (e.g. Marzouk et al. 2017). The primary finding of this study was that project emissions should be kept at a satisfactory level. Given that the authors identified six types of construction project emissions, using BIM as a tool for calculating these emissions should be interesting to those concerned with sustainability.

Similarly, as of 2017 a new trend has appeared using BIM technology for heritage building projects. For instance, Baik (2017) conducted case study research on one of the most significant historic buildings in the Hijaz region: the Nasif Historic House. One of the most important features of this building, for which construction began in 1872, was that it took nine years to complete. In addition, the structure comprises five levels, each with its own function, along with unique Mashrabiyahs and Rowshans (i.e. wooden lattice windows). These features led King Abdulaziz to choose this building as his favourite residence when visiting Jeddah city. The aim of Baik's study was to document the historic buildings that represent Islamic Hijazi architecture in Saudi Arabia, for which a shortage of data exist. This type of research could facilitate later repair or reconstruction of Saudi historic buildings.

This discussion highlights the problem that is addressed in this study, which concerns not only the importance of adopting digital collaboration approaches using BIM in design offices, but also the deficiencies in communication that often occur in the design phase. This approach supports the findings of Sultan (2009), who suggested that architects should not only recognise the need to develop their offices, but also the risks and future challenges these offices face. As a result, he recommended that academics, developers and government institutions, particularly those involved in both public and private engineering projects, should stop, reflect and review the performance of these institutions and restructure them appropriately in part by adopting modern technologies (Sultan 2009). Moreover, because the

successful adoption of new technology strongly correlates with successful communication practices, one objective of this study was to explore these factors and their influence on the collaborative design environment, particularly among various professionals. Accordingly, the next section presents these factors by reviewing the BIM literature and discussing the dynamic processes related to the three main pillars that underpin this research: communication, team, and collaborative environments.

2.3 Building information modeling (BIM)

This section situates this study within the BIM literature. The researcher reviewed this literature to explore the current research trends for BIM (see Table 2-2) with the primary objective of identifying current research trends that examine the use of BIM for the communication process in general, and communication channels in particular. However, it was first necessary to understand how BIM is defined, and a number of definitions are presented here. Moreover, it is important to mention that exploring these definitions can reflect an underlying philosophy behind BIM implementation, or the mechanisms used.

2.3.1 Definitions of building information modeling (BIM)

To understand the implications of BIM execution on the mechanisms used for communication, one must first define the term. A number of definitions from researchers and professionals for BIM exist in the literature, and they describe BIM in various ways. For some, BIM is "*a modeling technology and an associated group of processes to produce, communicate, and analyze building models*" (Eastman et al. 2008: 13). For Nour (2012: 1), BIM constitutes *"data sharing and not only data exchange."* For others, BIM is an integrated model (Sebastian 2011), a software application (Aranda-Mena et al, 2009: 420), a process (Haron et al. 2009) or shared digital representations and language that allow for interoperability (McGraw-Hill 2008). Moreover, many consider BIM to be a methodology (Succar et al, 2014; Ciribini et al, 2016). Penttilä (2006:403) described BIM as *"a methodology to manage essential building design and project data in digital format throughout the building's life-cycle."*

In view of this, such diversity of definitions for BIM across these studies on BIM suggests that they reflect various philosophies of why practitioners use BIM in their work. In other words, one could conclude that some ambiguity exists in understanding BIM as a concept (Aranda-

Mena et al, 2009). Consequently, this issue led the researcher to consider this ambiguity at the empirical study stage. In line with the BIM concept, some researchers consider BIM to be a socio-technical system (e.g. Sackey et al. 2014; Liu et al. 2016), *"because it is made up both of technical dimensions, e.g. 3Dmodeling, and dimensions with social impact, e.g. process reengineering"*(Liu et al. 2016:1). The following section reviews the BIM literature.

2.3.2 BIM literature

A review of the BIM literature revealed two leading trends in BIM research. The first trend primarily focuses on the context of *"organizations*" that use BIM through exploring the organizational challenges, benefits and risks associated with BIM implementation. The second trend focuses more on the *"technical" aspects* of BIM technology, such as 3D visualisation and clash detection. Both of those trends are discussed in the following sub-sections.

2.3.2.1 Organizational trends

With respect to the first research trend, organisation, it appears that the challenges of integrating BIM into architectural practices are relatively similar to the scenario of computer-aided design (CAD) technology; when this technology was first adopted by the architectural design field (Coates et al. 2010). This led to the finding that to date most BIM research has focused on exploring the challenges of implementing BIM for organisations. The literature identified several influential factors that affect this implementation that relate to three elements: processes, people, or organisational environment see Table (2-2). This section clarifies this categorisation.

2.3.2.1.1 Challenges of BIM implementation

With respect to organisational challenges, Dossick and Neff (2010) conducted year-long ethnographic observations of mechanical, electrical and plumbing (MEP) systems processes for two US commercial construction projects, for which they interviewed 65 industry leaders. The study results revealed that organisational challenges impeded collaboration among project participants. In addition, Ghaffarianhoseini et al. (2016) identified the risks of adopting BIM approaches in the architecture, engineering, and construction (AEC) disciplines, despite that the technology has been in use since 2000. Consequently, many studies have highlighted challenges facing BIM implementation. Dossick and Neff (2010) identified a number of significant challenges that consistently appear in the BIM literature, including

ineffective leadership (Dossick and Neff 2010), the conflict process (Rowlinson et al. 2010; Dossick and Neff 2010; Hooper and Ekholm 2010), organizational culture (Dossick and Neff 2010), team culture (Dossick and Neff 2010; Rowlinson et al. 2010), and resistance to change (Dossick and Neff 2010; Eadie et al. 2013; Rowlinson et al. 2010). The literature also reveals additional challenges to BIM implementation, such as lack of professional knowledge and experience (Eadie et al. 2013; Goes and Santos 2011), lack of client demand (Brewer and Gajendran 2010; Linderoth 2010), and lack of trust and communication among parties (Liu et al. 2016).

Similarly, various rationales have emerged for the reluctance of design professionals to adopt BIM approaches. For example, in a survey of over 100 UK employees, Eadie et al. (2013) found three primary reasons for delays in implementing BIM: lack of organisational expertise, lack of project team expertise, and lack of client demand. The authors also found several additional factors that hinder BIM implementation, including cultural resistance, investment costs, lack of financial support, resistance at the operational level, general reluctance of team members to share information, lack of project team communication with owners and each other, lack of apparent benefits from projects delivered to date, and Legal issues surrounding ownership.

Along the same lines, Rowlinson et al. (2010) conducted a Hong Kong study on two cases, and found that effective cooperation and collaboration on projects that employ BIM approaches depends on the level of social infrastructure and relationship management within the project team. In support of this finding, Ghaffarianhoseini et al. (2016) reported four key factors that should be taken into the consideration when implementing BIM approaches: a) management support; b) organisational culture; c) technical support; and d) BIM compatibility skills. In addition, Son et al. (2015) and Liu et al. (2016) categorised some of the aforementioned factors as influential in the success of the BIM implementation.

In addition, the literature has shifted focus from organisational aspects to the core units that constitute an organisation which is the architect (i.e. a people-team). Recently, in regards to the BIM literature, some studies have begun to analyse the factors that influence the degree of acceptance from an architect's perspective, reflected in behaviour, when adopting BIM (e.g. Son et al. 2015). For this study, the authors found a positive correlation between training and education with the perception of architects of the usefulness, effectiveness, and ease use of adopting BIM. In addition, results showed individuals to be the fundamental unit

of collaboration in BIM processes. Sebastian (2011) explored to what extent using BIM changes the roles of integrated stakeholders throughout the collaborative design process. In this study, the results suggested that any changes in these roles are generally coupled with changes in the relationships among project participants, which was largely due to the collaborative nature of using BIM that allows design and engineering processes to be performed concurrently. Moreover, the author found that activities such as detailed engineering and specifications can shift to earlier design phases. However, the same study also noted that one of the five main factors identified for successful BIM collaboration is the team environment.

2.3.2.1.2 Benefits of using BIM

Despite the various challenges to BIM implementation reported in the literature, many studies have examined the clear benefits of this process and its results in practice (e.g. Goes and Santos 2011; Azhar et al. 2007; Hooper and Ekholm 2010; Ghaffarianhoseini et al. 2016). With reference to the BIM's benefits, Ghaffarianhoseini et al. (2016) Identified a number of these benefits that are consistent with the literature, such as those related to: 1) technical benefits 2) knowledge management benefits; 3) standardisation benefits; 4) diversity management benefits; 5) integration benefits; 6) economic benefits; 7) planning and scheduling benefits; and 8) decision support benefits.

In line with these advantages, Barlish and Sullivan (2012), found 12 top benefits of BIM integration that occurred most frequently in the literature, such as communication, visualisation, and reduced requests for information (RFIs). The researchers also identified several factors that are associated with the success of projects that employ BIM methods, such as: 1) project team communication; 2) team expertise; 3) project size; and 4) other organisational external factors. In light of this, Barlish and Sullivan (2012), found that four primary factors determine the success of BIM projects: the staff (i.e. the team), the process (e.g. communication), the work environment, and the project itself (e.g. product size). Here it is important to mention that three of these factors (i.e. process, team, and environment) have been categorised in cross-profession collaboration theory as the key three determinants of collaboration success (see Section 2.4.3). It is also important to note that this theory was derived from qualitative and quantitative data (Amabile et al. 2001).

In addition, Liu et al. (2016) considered the aforementioned elements as the main requirements for successful BIM implementation. This study explored the implications of

using BIM on collaborative design and construction projects in China through a socio-technical system perspective. The authors analysed data from focus group discussions with 11 representatives from leading organisations and 12 semi-structured interviews, from which eight themes emerged: 1) communication, 2) leadership, 3) learning and experience, 4) attitudes and behaviour, 5) role-taking, 6) IT capacity, 7) technology management and 8) trust. These themes were then classified along three dimensions which are: process, people, and technology. In the light of this, this study disclosed that the successful BIM implementation requires for three primary components which are a process, people, technology and their categorizations. In addition to this, the authors concluded that many BIM projects still face organisational challenges that impede collaboration and identified a pressing need for improving BIM tools for in-depth communication, stating that BIM is *"more adopted for commercial propaganda and negotiation with clients*" (Liu et al. 2016: 8). With respect to organisational processes, Coates et al. (2010) stated that the architectural design process involves tasks such as thinking, creating, collecting, connecting and correcting, and as a result, a number of management and communication processes are required to achieve these tasks.

All of the aforementioned studies reflect the role three primary factors: process, team and environment play in the success of BIM implementation within an organisational context. It is worth noting, however, that a few academics identified technology as either a fourth factor or one that replaces the environment dimension (e.g. Liu et al. 2016).

2.3.2.2 Technical trends

One of the main trends in BIM literature is the organisational work environment and its challenges, risks, and benefits. The second trend is related to the technical benefits of BIM in practice.

To date, several studies have investigated the technical aspects of adopting BIM by focusing on their associated challenges and developing frameworks, or technology-based solutions to facilitate the synchronous collaboration of the BIM models (Isikdag and Underwood 2010), or cloud-based BIM systems (Li et al. 2014). Other research has focused simply on the implications of one of the BIM's technical benefits, such as 3D visualization, synchronization of design drawings or clash detection (Haron et al. 2009) and Interoperability (Ciribini et al. 2016).

In addition, researchers have investigated how to develop effective communication and coordination efforts for BIM-based design coordination processes. For example, Wang et al. (2016) developed a prototype plug-in for design coordination applications (e.g. Autodesk Naviswork Manage). Such prototypes enable the capture of information generated during the coordination process and the documentation and representation of this information with the aim to improve MEP design coordination.

Arguably, a review of the literature on these technical aspects suggests that these attempts focus on improving the process of sharing and exchanging information among project participants. This supports Isikdag and Underwood (2010:546), who stated that *''BIM acts as a shared information backbone through the lifecycle of the project."*

This discussion highlighted the two main trends in BIM research: the organisational and the technical trends (see Table 2-1) and presented the challenges of and rationales behind implementing BIM technology within organisations. The discussion also concluded that process, people, and work environment are three factors that emerge in the majority of the literature, and that these factors are essential to the success of collaborative environments using BIM technology (Barlish and Sullivan, 2012; Haron, 2009).

In terms of BIM research on communication, some researchers have investigated the implications of using BIM in the communication and collaboration process. For example, Dossick and Neff (2011) conducted a three-year ethnographic study across five teams and interviewed 71 project participants to identify the potential communication practices required for the use of BIM technology. In this study, the researchers focused on the verbal communication, conversation and dialogue of study participants during weekly group meetings that focused on clash detection. The study results suggested that, *"BIM does not replace talk [either] for problem-solving or finding optimal solutions…"* (Dossick and Neff 2011:84). This study focused on FTF meetings and found a significant need for the messy talk (i.e. active, informal and flexible conversation). The reason for this messy talk is that the BIM technology supports explicit digital information which can answer the question of 'what' is in the design model. However, the reasoning of 'why', for example, a material was selected needs discussion to understand issues and identify solutions. Such tacit knowledge is acquired from long experience and BIM technology cannot replace it. In this respect, it is important to investigate what the implications of using BIM are on communication channels other than in FTF meeting meetings. Specifically, whether the BIM technology also changed other channels or not? And, what are other reasons for changes in other communication channels? To bridge

this gap, this PhD study will continue in this trend to explore what is happening to the communication channels, and why?

To situate this study in its research context, a further assessment was made of several review papers (see Table 2-1). For example, Yalcinkaya and Singh (2015) presented a comprehensive survey of BIM research patterns and directions by reviewing 975 papers published between 2004 and 2014. This study summarised 12 principles of BIM research areas and presented the most-cited studies for each principle. However, the authors did not identify BIM communication process as an independent principle, nor did they single out communication channels in particular. In addition, Volk et al. (2014) reviewed the implementation of BIM processes for existing buildings, but did not mention potential changes in communication channels in this context. However, in a review of 126 BIM-related papers published between 2007 and 2015, He et al. (2015) categorised BIM research trends and future directions into five areas that included processes, people, and work environments.

Table 2-1: Overview of recent review papers on BIM research

Title	Author	Journal Name	Number of reviewed papers	Emerging BIM research areas
Patterns and trends in Building Information Modeling (BIM) research: A Latent Semantic Analysis	**Yalcinkaya and Singh (2015)**	Automation in Construction	975 abstracts for academic papers (2004-2014)	"In summary, the labels of the 12 principle BIM research areas - grouped under (4) four main BIM research streams that are: (1) Implementation through various phases of project lifecycle,(2) BIM education and training for students as well as professionals, (3) BIM-based design and analysis, and (4) BIM technologies to *facilitate information exchange and interoperability.*" (p.72)
Building Information Modeling (BIM) for existing buildings: Literature review and future needs	**Volk et al. (2014)**		180 papers	Results show limited BIM implementation in existing buildings to date due to challenges of: (1) high modelling/conversion efforts of captured building data into semantic BIM objects; (2) updating BIM information; and (3) processing of uncertain BIM data, objects and relationships for existing buildings.
Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis	**He et al. (2015)**	International Journal of Project Management	126 papers published in 16 academic journals (2007-2015)	Identified five principal research areas of the managerial areas of BIM: 1) work environment (environment); 2) application approach (means); 3) conceptual framework (product); 4) adoption process (process); 5) stakeholders and actors (people)

In general, the review on BIM literature revealed a lack of communication-related studies, particularly with respect to communication channels. For this reason, there is a need for a more thorough understanding BIM-related communication processes that is derived from theory and research. For example, questions surrounding these communication processes, their elements, and the factors that affect their success are as yet not fully addressed in the literature. These questions are be discussed in the following section.

Table 2-2: Classification and summary of BIM literature in terms of recent research orientation, research strategies and methods employed

Studies	Classifications	Classification unit i.e. people (Pe), processes (Pr) and environment (En)			Research Strategies and Methods		
		(Pe)	(Pr)	(En)	Theory	Research Strategies	Data Collection Methods
Dossick and Neff (2010)	*Organization-oriented*	√	√	√	-	Ethnographic	Year-long observations for two commercial construction projects; 65 interviews with US industry leaders
Liu et al. (2016)		√	√	Tech	Socio-technical systems	Case study	Data collection for 6 months in 2015 using: 12 semi-structured interviews; focus groups with 11 representatives from leading Chinese companies
Volk et al. (2014)		√	√	√	-	Review paper	Review of over 180 recent publications on using BIM for existing buildings and future needs
Ghaffarianhoseini et al. (2016)		√	√	√	-	Review paper	-
Barlish and Sullivan (2012)		√	√	√	Analysed 600 and found 21 sources of the highest frequency within the past decade; used case study, survey, theory and general assumption, and model or process methods	Case study	Three case studies of three BIM projects at one firm
Coates et al. (2010)		√	√	√	-	Review paper	-
Rowlinson et al. (2010)		√	√	√	-	Case study	Two Hong Kong case studies
Azhar et al. (2007)		√	√	-	-	Survey and case study	Three questionnaires; ten BIM construction projects
Hooper and Ekholm (2010)		√	√	√	-	Case study	Observation and interviews in Sweden
Eadie et al. (2013)		√	√	√	-	Survey	Online questionnaire for BIM users; Interviews with key BIM adopters for pilot study. Then, survey of

							over 100 UK employees
Succar et al. (2014)		√	√	√	-	-	Developed framework for BIM performance measurement for Australia
Son et al. (2015)		√	√	√	-	Survey	In-person Interviews with 162 architects across three design organizations in Korea; structured questionnaire
Linderoth (2010)		√	√	√	Actor-network theory	Case study	17 semi-structured interviews on different hierarchical levels within organisations; participant observation of 45 meetings (80 total hours) in Sweden
Sebastian (2011)		√	√	√	-	Case study	Observation of two ongoing pilot projects in the Netherlands
Dossick and Neff (2011)		√	√	√	-	Ethnographic	Observation of five teams collaborating on three commercial and institutional building projects over 8-10 months; 70 participant interviews in the US
Goes and Santos (2011)	***Technical- Oriented***	√	√	√	-	Case study	Two case studies in Brazil
Haron et al. (2009)		√	√	Tech	-	Review paper	-
Isikdag and Underwood (2010)		-	√	-	-	-	Review of storage and exchange mechanisms for BIM; proposal for two design to facilitate model-based synchronous collaboration
Wang et al. (2016)		√	√	Tech	-	Experimental study	Expert interviews and protocol analysis; design and prototype of a plug-in for, Autodesk Navisworks Manage
Ciribini et al. (2016)		√	√	Tech	-	Case study	Tested advantages of BIM interoperability on the first official BIM project in Italy

2.4 Theoretical and conceptual framework

In conducting this research, three different sets of concepts were mobilised in aim to understand the dynamic processes of communication processes across diverse professionals in general, and within BIM collaborative environments in particular. For that reason, this section establishes theoretical and conceptual foundation for this research that was essential to exploring the factors that influence these processes. In addition, sections 2.4 and 2.5 discuss the analytical framework and identify the main themes of this study.

The first section outlines the context of this study by presenting relevant theories and literature from three core areas that establish the foundation of this study: (1) communication processes; (2) virtual teams; and (3) collaboration.

Moving from that, the second section categorises and compares the factors across the main themes, which helped in the development of an analytical framework for examining the implications of using BIM on communication channels.

2.4.1 Communication processes: Theoretical background

Recently, the architecture, engineering and construction industries have faced a paradigm shift from document-centric activity to a data-centric activity (Xue et al. 2012). From a management perspective, the foundation of building information modeling processes is based primarily on communication that enables stakeholders to collaborate effectively (Xue et al. 2012). Therefore, in order to understand how these communication processes function, the following part introduces communication processes from various theoretical perspectives.

2.4.1.1 Communication definitions

In the communication literature, most definitions of communication reflect at least two perspectives. The first describes communication as *'a process of exchange of information between sender and receiver to equalize information on both sides'* (Otter and Prins 2002). This definition focuses on the transmission aspect of the communication process and is commonly expressed as a linear model of a *'one way process'* (Eckert et al. 2005). Conversely, the second perspective describes communication processes as *'transmitting messages from one person and the receiving (and successful understanding) of those messages by another'* (Torrington and Hall 1998:112). This definition is consistent with Rogers and Kincaid (1981:63), who described communication as *'a process in which the participants create and share information with one another in order to reach a mutual understanding.'* Emmitt and Gorse (2009) described this interpretation as one of the more *'robust definitions'* of communication, and defined communication as the *'sharing of meaning to reach a mutual understanding and to gain a response,'* which has been broadly applied in the communication literature (Emmitt and Gorse 2007:3). In sum, all of these definitions emphasise equal understanding in communication processes rather than measuring flows of information (Maier et al. 2008).

In terms of the design process, it seems that a mutually shared understating between project participants is a fundamental prerequisite for the success of any communication process (Eckert et al. 2005). However, it is also apparent that some communication studies mirror the concept of the aforementioned first perspective on communication in terms of sharing information equally. However, these differing definitions reflect Eckert et al.'s (2005) call for the pressing need for architectural firms to develop the notion of developing 'mutual participation' among project stakeholders.

However, from the researcher's point of view, and for the purpose of this study, this step was fundamental in understanding these two different perspectives (i.e. concepts) on communication. This, in turn, helps to understand the dynamic processes of communication within a design process context in depth, from a theoretical lens. The researcher began this process by reviewing the most commonly applied perspectives on communication in order to determine the most appropriate theoretical communication models for this study.

2.4.1.2 Theoretical perspectives of different communication models: Linear and circular models

To understand how these two perspectives can help to investigate the various forms of communication practices that occur in the design process, the researcher followed the Eckert et al. (2005). In order to identify the key factors that influence the dynamic process of communication, the researcher introduced several theoretical models, including the linear model i.e. one-way processes (Shannon and Weaver, 1949); the interactive model i.e. two-way process (Defleur, 1966); and Schramm's communication model (1954), which discusses fields of experience and encoding knowledge skills.

2.4.1.2.1 Shannon and Weaver (1949): Communication as a linear process

Shannon and Weaver (1949) established the most widely applied interpersonal communication model (Dainty et al. 2006). This model proposed that communication processes consist of key elements; source (i.e. sender), transmitter, channel, receiver, destination, and last essential part is the 'noise.' Because this model was developed from the field of information theory, the author characterized communication as a one-way process. However, many have asserted that this model overlooks the essential role of feedback (Emmitt and Gorse 2007; Dainty et al. 2006). As a result, one of the shortcomings of this

transmission model is the absence of the role of the receiver (Emmitt and Gorse 2009). According to this model, the decision maker is the communication source and her intended receiver is inert; the sender relays a message, and the receiver does not actively participate in the communication process (Dainty et al. 2006). This could explain one pattern of the four communication interaction types which were identified by McQuail (1994): an active sender and the passive reaction from the recipient. As a result, many researchers, such as Emmitt and Gorse (2009), consider this model to be most applicable for studying mass communication processes, in which information is disseminated to many recipients. Therefore, in order for a sender to transmit a message to multiple passive receivers, the message needs to be transmitted through effective channels (Dainty et al. 2006). Another shortcoming of this model is that it focuses solely on 'technical disruption,' this element has the potential to influence a channel's performance in transmitting electronic signals (Dainty et al. 2006).

In sum, Shannon and Weaver's (1949) model excluded a number of important considerations, such as communication environments, role of recipients, and feedback, and focused more on communication channels. In the case of this model, the channel was the telephone, and underpinning theory was information theory (Emmitt and Gorse 2009). As a result, one could conclude that this type of communication channel (i.e. the telephone) provides a linear flow of information (i.e. one-way process) with no opportunity for feedback (Dainty et al. 2007). In an AEC project context, examples of this type of channel include letters, drawings and emails which according to Dainty et al. (2007) are one-way communication channels. By contrast, communication channels such as meetings and conferences facilitate the flow of information with considerable opportunities for feedback (Dainty et al. 2007). This often presents challenges for organizations that use a range of communication channels. This, in turn, led to search for the two-way process as presented below.

2.4.1.2.2 DeFleur's communication model: The effects of the feedback on the communication process

DeFleur's communication model (1966), is based on the Shannon and Weaver and the Westley and McLean models of communication. One important aspect of DeFleur's model is that it characterizes communication as a two-way process (Emmitt and Gorse 2003). Furthermore, this model first introduced the concept of two-way feedback (Emmitt and Gorse 2003), which contributed to changing the perception of communication processes from linear

to circular. Furthermore, this model suggested that 'noise' may emerge at any stage of a communication process. This suggests that communication environments play a critical role in affecting the performance of communication processes, which stands in contrast to the Shannon and Weaver's (1949) model, which does not address the physical and social context in which communication occurs (Dainty et al. 2006). Therefore, according to DeFleur's model, any factor involved in a given communication environment can influence the efficiency of communication processes. However, this model does not take into account the requirement of a common basis of knowledge for more effective interpretation. Therefore, the next section will explore this factor by Schramm communication model.

2.4.1.2.3 Schramm communication model (1954)

Schramm's communication model (1954) was rooted in the Shannon and Weaver model (Schramm 1997), but one contribution Schramm made was in considering the experience of both sender and receiver as a critical factor in communication (Croft, 2004). According to this model, two processes are necessary for effective communication encoding and decoding without which information can never flow among two actors (Croft, 2004). In other words, in the absence of shared experience between a sender and receiver, communication cannot occur (Dainty et al. 2006). In addition, Schramm's model adopted DeFleur's principle of two-way feedback (Croft, 2004).

In respect to the design context, and based on these theoretical models it is clear that communication processes constitute far more than a complex set of signals; rather, they are interactive processes in which information is circulated among participants with the aim to achieve mutual understanding (Eckert et al. 2005). Furthermore, this overview of communication models shows that shared mutual understanding is required for effective feedback between professionals, and that this cannot be achieved without sharing common knowledge. The latter point concerns effective encoding and decoding processes, as deficiencies in these processes is considered to be one of the main challenges in the construction industry: misinterpretation (Dainty et al. 2007), as discussed in Section 2.5.1.4 and 2.5.3.3.

With respect to perspectives on communication and theoretical models, successful communication processes are clearly governed by a number of primary factors, including degree of two-way feedback, shared understanding and professional experience, engaged participants, common knowledge of encoding and decoding, technical noise (which in the

1940's was considered to be any interference with the signal), and the communication environment. These factors and their influence on communication channels will be more fully discussed in Section 2.5.

This discussion illustrates the importance of architects and their organizations understanding communication models and employing them in their practice (Eckert et al. 2005). As Dainty et al. (2007) asserted, this understanding can help to explain why actors in design firms often fail to communicate effectively and to establish new methods for improving communication performance.

2.4.1.3 Communication forms and methods

This section presents various communication forms and methods of the communication that often occur in the design context. Generally speaking, communication can be divided into two types: verbal, which involves speech and nonverbal, which employs body language (Hatem et al. 2012), sketches (Eckert et al. 2005) or documents (Hatem et al. 2012), to name a few. For example, in face-to-face (FTF) dialogue, at least 50% of the communication is generally non-verbal (Goffman 1959). In addition, in a design context another means of information exchange through FTF meetings which is the exchange of paper documentation (Hatem et al. 2012). Communication methods within professional contexts can also be either formal or informal. For example, formal communication would take place during meetings at which formal decisions are made (Dainty et al., 2006). Informal communication is communication that occurs between professionals in a more informal environment (Dainty et al., 2006). However, given the recent growth in digital network speeds, information communication technology (ICT) offers the opportunity to communicate in new and various ways, from text, online chatting or visual communication through webcams (Hatem et al. 2012).

2.4.1.4 Relevant literature on the importance of communication in design processes

The significance of effective communication in the success of design processes is well documented in the theoretical literature (Maier et al. 2009). In collaborative design environments, communication often becomes complex, and members have a range of choices in communication channels (Gabriel and Maher 2002; Eckert et al. 2005). In fact, a

review of the literature on virtual and distributed work environments reveals that communication is the *'most researched construct'* (Watson-Manheim and Belanger 2002), and is considered a fundamental foundation for both virtual work and organizations (Ocker and Fjermestad 2008; Eckert et al. 2005).

With respect to the importance of communication in architectural organisations, (Chiu 2002) conducted a study of two design firms to identify the purpose of and the time spent on employee communication. The study results estimated that 78% of communication at these firms related to solving design problems, while 21% related to defining these problems. In addition, 65% of respondents considered unclear design information and messages as the main causes of ineffective feedback. The author also found that an average of 40% of project time was used for communication, while 50% was used for drafting and design, with 10% of devoted to tasks. Importantly, this study found that at both firms, employee preference governed the use of communication channels. This study suggests that more effective design communication may not only lead to improved performance but also save time and project resources.

In line with previous communication environment studies, more difficulties have arisen due to the preferences of individuals in using communication channels (Watson-Manheim and Belanger 2002). This has lead to additional findings, particularly with respect to collaboration among project teams for which individual preferences must to be taken into account (Watson-Manheim and Belanger 2002; Maier et al. 2008).

Due to the essential role communication processes play and the impact of communication channels, many studies have examined the effect various communication channels, such as FTF conversation and video-conferencing, have on collaborative work (Chiu and Cheng-kung 2002; Gabriel and Maher 2002). To date, most architects who work in the same location have most likely chosen FTF communication when collaborating with other professionals (Gabriel and Maher 2002). However, due to recent developments in communication technologies, such as CAD, geographic distance has diversified the way these professionals communicate and visualize design representations (Gabriel and Maher 2002). Such developments have led many architectural firms to adopt new technologies and internet connections to exchange design information (Gabriel and Maher 2002). In this case, the goal of using new communication technologies is to facilitate the transfer of this information clearly and quickly (Maier et al. 2008; Eckert et al. 2005; Dossick and Neff 2011; Ocker and Fjermestad 2008).

There are many research methods to be found in the literature of communication. For example, Eckert et al. (2005) found that many of communication design process studies employ a combination of methods, such as observation, experiments, and interviews. Watson-Manheim and Belanger (2002) also examined a number of factors that influence communication mode choice. However, a gap exists in the literature concerning the potential impact of collaborative tools, such as BIM, in changing the mechanism used for communication channels for architects and the factors that influence these issues. Therefore, the next step is to further investigate these factors from a design team perspective.

2.4.2 From communication processes to virtual team characteristics

In the context of the design process, it is fundamental to understand the core role team members play by highlighting the factors that influence their performance and the extent to which these factors can affect the communication process. According to communication theory, those working in virtual teams (VT) play two different roles that represent the core elements of communication processes: senders and receivers. This section explores these factors and the associated challenges that commonly arise in virtual team environments.

2.4.2.1 Virtual team definition

A combination of synchronous and asynchronous communication technologies has reduced face-to-face interaction among project teams and accelerated the phenomenon of the 'virtual team' (VT) (Tucker and Abbasi, 2012). Cochrane et al. (2008:2) defined *virtual team* as a *'team whose members share a common purpose or goal, work interdependently and are geographically isolated from one another.'* However, Paré and Dubé (1999:479) described VT as similar to any other team in which *'a group of people interact through interdependent tasks guided by a common purpose,'* through information and communication technologies (ICT) across time, space and organisational boundaries. Similarly, Lipnack and Stamps (1997) added that VT communication activities are largely facilitated through computer-mediated systems (CMS).

On the other hand, a review of the virtual team literature by Ale Ebrahim et al. (2009) suggested that Powell et al. (2004) authored one of the most widely accepted definitions of VT, in which *'groups of geographically, organizationally and/or time dispersed workers brought together by information technologies to accomplish one or more organization tasks*.' Significantly, Fisher et al. (1998) stated that VT are often more diverse than conventional

teams, as their members are more likely to be from different cultures and have diverse technical specialities, linguistic backgrounds and organisational allegiances. However, despite its advantages, this diversity and complexity in VT environments often presents challenges (Powell et al. 2004; Ale Ebrahim et al. 2009; Brennen et al. 2007).

2.4.2.2 Challenges for virtual teams

Over the last decade, researchers have identified many obstacles that virtual teams commonly face, including difficulties in maintaining an understanding of team activities; managing conflicts; coordinating tasks; sharing knowledge and team identities; building trust (Ocker and Fjermestad 2008); creating team cohesiveness (Dineen 2005); and promoting social interaction (Powell et al. 2004). In addition, Cramton (2001); and Mark (2001) found a number of communication-related challenges common to virtual teams, such as delays in sending feedback, the lack of a common frame of reference for participants, differences in interpreting information, and lags in participation from remote team members.

With respect to the role communication plays in VTs, Powell et al. (2004:9) indicated that *'a lot of these challenges are rooted in team communication behaviors and processes.'* For example, Jarvenpaa and Leidner (1999) has found that regular and timely feedback is the key to building trust in a VT and is associated with improved team performance. A further challenge VTs often face concerns issues with non-verbal communication, which is considered an essential element in communication between team members that is often overlooked (Sproull et al. 1992).

One type of non-verbal communication that is commonly used in the design process is hand sketching. Both Sebastian (2011) and Homayouni et al. (2010) characterised 'sketching' as a procedural strategy used encourage clear communication. And while BIM-enabled projects may require less hand sketching, this technique has remained a vital communication tool during project design meetings (Sebastian, 2011). In fact, sketching is considered to be part of a 'visual language.' and a great deal of information is often contained in that language that can be lost when information is *'coming off of high-speed plotters'* (Homayouni et al., 2010:784). Furthermore, face-to-face communication plays a critical role in VT and project processes (Paré and Dubé 1999, Ale Ebrahim et al. 2009). And while resources must be allocated in bringing teams together for face-to-face meetings, they can help team members

build trust and agree upon work methods terms through learning about common methodologies and a shared use of language (Geber 1995).

Additionally, many studies discuss the importance of communication in VT by focusing on training communicators and adopting technology approaches. Powell et al. (2004) confirmed this through a review of 43 papers on VT and presented several issues. In addition, the authors found that communication is a key factor in effective VT performance. Therefore, if a VT is one of the building blocks of successful organisations (Powell et al. 2004) and technology is a foundation of virtual business relationships, then *'communication is the cement'* (Hulnick 2000: 33).

2.4.2.3 Characteristics of effective teamwork approaches

Tucker and Abbasi (2012) categorised the key elements of effective teams as: 1) goals and objectives; 2) structure and planning; 3) communication and information exchange; 4) cooperation and interdependence; 5) evaluation and reflection; and 6) leadership and accountability. Furthermore, they identified the characteristics of effective teamwork in a collaborative context to be showing commitment to the overall team purpose, cooperative work with others, active participation in team activities, support, and encouragement (Tucker and Abbasi, 2012). However, in terms of communication contexts, the authors identified the characteristics for effective teamwork as maintaining an open environment of free expression, encouraging a clear and concise expression of thoughts, and reflective listening (Tucker and Abbasi, 2012).

In terms of virtual teamwork, most studies consider communication to be a core element. For example, Elbrahim et al. (2009) reviewed the definitions, types and underlying characteristics of virtual teams and 12 key factors for virtual teamwork success. However, other scholars, such as Dineen (2005) and Powell et al. (2004), maintained that some ambiguity remains regarding the factors that impact the effectiveness of virtual teams. In addition, Elbrahim et al. (2009) emphasised the essential role team managers play in selecting and training appropriate staff. These factors could also be fundamental for teams with members who straddle various disciplines, both in increasing cohesiveness and satisfaction (Hertel et al. 2005; Dekker et al. 2008) as well as building effective teams (Tucker and Abbasi, 2012).

Based on team theory literature and empirical evidence, Brennen et al. (2007) developed a causal map model that identified key factors for team performance, including knowledge, communication, feedback, monitoring, and leadership. These factors were mapped according to their influence on each other, with arrows indicating the direction of influence and signs representing the nature of this influence. This study applied a quantitative approach using interview data from five UK Royal Navy firefighters. With respect to the role of communication in team performance, the resulting model suggests that monitoring is positively linked to feedback and communication and a direct link between communication and dynamic knowledge of situations. Consequently, the authors found that increasing levels of communication (i.e. how information is processed and exchanged) can lead to improved task performance and team efficacy due to an increase in information availability. As a result, they stated that *'…ensuring effective teamwork is even more critical than technological advances as both lead to increased information availability'* (Brennen et al. 2007: 995).

Based on this discussion, none of these studies explicitly mentioned either direct or indirect effects in terms of the communication channels that were employed.

2.4.3 Cross-profession collaboration theory

A review of the literature on communication processes and virtual teams suggests that ambiguity remains as to the extent to which BIM has potentially changed or replaced communication channels between participants and, if so, what the underlying root causes behind these changes might be. As a result, an understanding is needed about how communication processes work in this context and of the essential role of communication environments, particularly with respect to research that focuses on communication processes in BIM collaborative environments. This, in turn, suggests a search for further factors from a collaborative research perspective that could play a role in or contribute to changes in communication channels, particularly given that design processes involve professionals from diverse professions.

Because of the diversity across design disciplines, there is high demand for improving collaboration within multidisciplinary teams. In light of this, Amabile et al. (2001) developed a conceptual model for cross-profession collaboration theory by reviewing relevant theory and empirical evidence from general collaboration literature. This literature yielded insights into three determinants of cross-professional success: 1) collaborative team characteristics; 2)

collaboration environment characteristics; and 3) collaboration processes. Under these categories, they also identified subcategories. This theory uses Jassawalla and Sashittal's (1998:239) definition of collaboration as a *'coming together of diverse interests and people to achieve a common purpose via interactions, information sharing, and coordination of activities'.* This definition considers 'individuals' as a basic element in the collaboration process that differs in prominent ways in terms of sharing information and working toward objectives. Following this, the model was tested for a 38-month period in an academic/practitioner research context using observations, interviews, surveys, informal discussions, and records of meetings for the research group members. The study aim was to understand collaboration and the factors that influence its success. To achieve this aim, the researchers studied a diverse professional team of seven academics and seven practitioners distributed across six companies.

With respect to the characteristics of collaborative teams, the authors found that leadership skills in managing team communications strongly influenced team performance. However, for collaboration environments, the study findings revealed the notable role of institutional factors play in supporting each collaborator. Furthermore, the authors found that the question of institutional support for each collaborator was absent in the collaboration literature (Amabile et al. 2001). Among collaboration process characteristics, they also found communication to be the most important factor during the collaborative process, which suggested that recurring, well-structured meetings with information that is exchanged beforehand are particularly important for further improving the success of collaborations success, especially if team members are remotely located.

It appears that Amabile et al.'s (2001) findings are consistent with the collaboration literature in terms of the importance of a clear understanding about the roles and responsibilities of collaborators at the outset (see Section 2.4.2). This suggests an inquiry into whether the absence of clarity in shared roles and responsibilities between participants could be one of the foundational factors in making changes in communication channels. At a fundamental level, Amabile et al.'s (2001) study demonstrates the strength of this conceptual model of the collaborative theory, and the authors maintained that such a model could be applied in other collaboration environments. Nevertheless, the potential weakness of this theory was its reliance on observation for much of the data collection (Amabile et al. 2001). Hence, the researchers recommended for using alternative cases and non-case study research methods,

which could allow for data collection across many cross-professional teams with diverse characteristics and structures.

This research drew on cross-professional collaboration theory by using the three main categories and sub-categories mentioned above in order to understand the causes and effects of using BIM technology in communication channels used within collaborative environments.

2.4.4 From concepts to factors

The above discussion reviewed the relevant literature and theories from diverse areas, i.e. communication, teamwork, and collaboration. This review was necessary due to the lack of specific studies on the role of BIM technology can play in changing communication channel across various professional environments. For this reason, and in response to the need to gain a deeper understanding of communication process among various professionals in BIM-enabled work environment, three theories from the communication process literature—team theory (Brennen et al. 2007), cross-profession collaboration theory (Amabile et al. 2001), and the aforementioned literature— were reviewed in parallel.

Following this, an exploration of the factors that concern changing communication channel mechanisms is the scope of this study. As result of this review, 38 potential influential factors emerged (see Table 2-3). It is important to note that the majority of these identified factors have been deemed influential in the literature regarding the performance of teamwork, communication, and collaboration processes. However, as was previously discussed, few of these factors have been investigated in terms of their influence in changing the mechanisms used for communication channels.

Identified factors affecting process performance include: 1) absence of sharing experiences between senders and receivers (e.g. Dainty et al. 2006; Ale Ebrahim et al. 2009; and Brennen et al. 2007); 2) lack of shared mutual understanding (e.g. Sclater et al. 2001; Shannon and Weaver 1949; and Eckert et al. 2005); 3) technical noise (e.g. Maier et al. 2008; Powell et al. 2004; Sclater et al. 2001; and Watson-Manheim and Belanger 2002); 4) lack of trust (e.g. Ocker and Fjermestad 2008); 5) delays in sending feedback (e.g. Cramton 2001; Mark 2001; and Brennen et al. 2007); and 6) leadership (e.g. Brennen et al. 2007; Amabile et al. 2001; and Ale Ebrahim et al. 2009), to name but a few.

Along these lines, factors that were identified in the literature as influential in changing communication channels include: employee preference (e.g. Chiu and Cheng-kung 2002; Watson-Manheim and Belanger 2002; and Maier et al. 2008); staff resistance to change (e.g. Sidawi and Omairi 2010; Watson-Manheim and Belanger 2002); and organizational culture, and lack of trust and reward structures (e.g. Watson-Manheim and Belanger 2002).

Importantly, in line with the BIM literature, many studies have consistently highlighted some of these factors either as challenges to BIM implementation or as influential factors in the successful implementation of BIM. Such factors include: ineffective leadership (e.g. Dossick and Neff 2010); conflict processes (e.g. Rowlinson et al. 2010; Dossick and Neff 2010; and Hooper and Ekholm 2010); organizational culture (e.g.Dossick and Neff 2010); team culture (e.g. Dossick and Neff 2010; Rowlinson et al. 2010); resistance to change (e.g. Dossick and Neff 2010; Eadie et al. 2013; and Rowlinson et al. 2010); lack of professional knowledge and experience (e.g. Eadie et al. 2013; Goes and Santos 2011; Al Soliman 2012; and Alshalhoob 2012); lack of client demand (e.g. Brewer and Gajendran 2010; Linderoth 2010), and lack of trust and communication among parties (e.g. Liu et al. 2016), to name but a few.

In addition, most literature on design communication emphasises the importance of face-to-face (FTF) meetings as opposed to computer-mediated communication (CMC). A commonly held view is that FTF meetings have been considered to be a core strategy for many organisations. From the perspective of the previous research, this view results from to the critical role FTF meetings play as a social processes that build trust and social relationships, and consequently encourage communication (Geber 1995; Dossick and Neff 2011; Powell et al. 2004; Eckert et al. 2010; Amabile et al. 2001; Sclater et al. 2001; and Paré and Dubé 1999). With respect to FTF conversation (i.e. verbal communication), recent studies have concluded that this is the most preferred communication channel for multicultural design teams for those who work at the same location (Gabriel and Maher 2002; Eckert et al. 2005). In addition, using hand sketching (i.e. non-verbal communication) during FTF meetings for BIM projects was also deemed important (Sebastian 2011; Homayouni et al. 2010; and Dossick and Neff 2010). Further, another common non-verbal communication type used in BIM-enabled work environments is email (Dossick and Neff 2011).

From what has been discussed so far, it is clear that FTF conversation remains a preferred and efficient way to communicate in collaborative work environments. In addition, and particularly in the Saudi context, it is significant that this preference is connected to limiting of communication channel types for design representation technology (i.e. CAD), which remain

the most preferred means for Saudi client engagement with design processes (Al Soliman 2012; Alshalhoob 2012).

It is worth noting that this review of the communication and virtual team literature suggests that considerable commonality exists in factors that influence the dynamic process of communication for virtual teams within collaborative environments. As a result, one of the main contributions of this research is to investigate what occurred with respect to the communication channels that were studied, and why. The following section presents some additional influential factors that emerged from the discussion in this current section along with the subsequent discussion of potential factors that appeared in the three sets of literature and relevant theories reviewed for this research.

2.5 Classifications of factors that can influence collaborative communication environments

This section discusses factors gleaned from three main sets of literature (communication, team, and collaboration) and relevant theory in terms of their potential influence on these areas and on the communication channels. As the table (2-3) shows, the literature suggests that considerable commonalities exist across these factors. However, despite these similarities, they differed in some regard. In light of this, this section is presented in stepwise fashion :

i. Identifying the possible influential factors from three different sets of literature and their corresponding citations;

ii. Listing definitions are taken from these sets of literature;

iii. Grouping the factors into themes;

iv. Comparing and rearranging these factors (i.e. by an iterative process);

v. Classifying these factors into three themes with corresponding sub-factors.

This classification system was developed to address the potential impact of these sub-factors on either the primary factors or the communication channels employed.

This process allowed for the identification of themes with the aim of developing an analytical framework to examine the effects of using BIM on communication channels. The three themes are: methodology of information exchange, collaborative team characteristics, and

leadership. Importantly, any overlap between the factors within or across each theme assisted in the development of the pilot study used in this research to examine if and how these factors are relevant in changing the communication channels employed. Such questions are introduced at the conclusion of each subsection.

Table 2-3: Main Table for the three themes

Categories (Themes)		Factors	Sub-factors
Theme #1	Methodology of information exchange	**1. Information Exchange Process** Including: 1. Face-to-Face communication 2. Virtual communication	▪ Exchange information before meetings and hold regular meetings (Amabile et al. 2001); collaboration theory
			▪ Regular and timely feedback (Mentioned in all three literatures) and in, (Amabile et al. 2001); collaboration theory
			▪ Non-verbal communication (ex. sketching) (Homayouni et al. 2010; Dossick and Neff 2011; Sebastian 2011); BIM research
			▪ Shared mutual understanding from in communication theory (Shannon and Weber); communication
			▪ Misunderstanding (Sclater et al. 2001); communication
			▪ Lack of information flow (Eckert et al. 2001); communication
			▪ Misinterpretation of information (Eckert et al. 2001); (Eckert et al. 2005); communication
			▪ Role of informal communication (referred to in communication LR as social interaction), improving trust and generating ideas (Ebrahim et al. 2009); team
		2. Information representation (Eckert et al. 2001); (Maier et al. 2008) (Gabriel and Maher 2002); communication	▪ Diversity of communication channels (Eckert et al. 2005); communication (Gabriel and Maher 2002); communication
			▪ Autonomy of task execution (Maier et al. 2008); communication
			▪ Interpretation of representation; rea- time interpretation (Eckert et al. 2005) ; communication
		3.Technical noise/challenges Shannon and Weaver (1949): Communication as a linear process (Maier et al. 2008); communication	▪ Handling technical conflicts (Maier et al. 2008); communication
			▪ Lack of Technical expertise (Powell et al. 2004); (Ebrahim et al. 2009); team

			▪ Lack of technical training and support (Powell et al. 2004); Team (Sclater 2001; Watson-Manheim & Belanger 2002) Communication
Theme #2	Collaboration team characteristics	**1.Project relevant skills and knowledge** (Amabile et al. 2001); Collaboration theory	▪ Diversity and complementarily in skills and common knowledge ▪ Diversity of perspectives ▪ Shared common knowledge (Amabile et al. 2001); collaboration theory (Ebrahim et al. 2009); (Brennen et al. 2007); team
		2. Collaboration skills (Tucker and Abbasi 2012); team (Amabile et al. 2001); Collaboration theory (Gabriel and Maher 2002); communication	▪ Experience in collaboration (Amabile et al. 2001); collaboration theory
			▪ Leadership skills (Amabile et al. 2001); collaboration theory
			▪ Compatibility in problem-solving skills (Amabile et al. 2001); collaboration theory
		3. Attitude and motivation (Amabile et al. 2001); collaboration theory	▪ Presence of mutual trust and respect (mentioned widely) (Maier et al. 2008); communication (Amabile et al. 2001); collaboration theory (Ebrahim et al. 2009); (Brennen et al.2007); team
			▪ Understanding of culture diversity (Amabile et al. 2001); collaboration theory
			▪ An open attitude towards diverse people and ideas. (Amabile et al. 2001); collaboration theory
			▪ Reward structure (Ebrahim et al. 2009); team (Watson-Manheim and Belanger 2002); communication
Theme #3	Leadership	**1. Leadership Roles** (Maier et al. 2008); (Fjermestad and Ocker 2007); (Maccoby 2000); (Spaho, 2013); communication (Ebrahim et al. 2009); (Brennen et al. 2007); (Shachaf 2005); team (Amabile et al. 2001); collaboration theory	▪ Appropriate selection of collaborators and developing their skills (Amabile et al. 2001); collaboration theory
			▪ Facilitating understanding about communicator roles and responsibilities (Amabile et al. 2001); collaboration theory (Shachaf 2005); communication
			▪ Availability of information for project parties (Maier et al. 2008); communication
			▪ Building trust (Maccoby 2000); (Maier et al. 2008); communication
		2. Conflict processes (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory	▪ Ineffective leadership (Ebrahim et al. 2009); (Tucker and Abbasi 2012); (Powell et al. 2004); team. (Spaho 2013); communication (Amabile et al. 2001); collaboration theory

		(Watson-Manheim and Belanger 2002); (Emmitt and Gorse 2003); communication	▪ Cultural diversity (Powell et al. 2004); team (Amabile et al. 2001); collaboration theory (Eckert et al. 2005); communication
			▪ Lack of mutual trust (Amabile et al. 2001); collaboration theory
			▪ Lack of mutual understanding DeFleur's communication model (1966); communication
			▪ Diversity of perspectives (Eckert et al. 2005); communication (Amabile et al. 2001); collaboration theory
			▪ Clarity in roles and responsibilities of team member according to their expertise and skill (Maier et al. 2008); (Sclater et al. 2001); communication (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory
		3. Institutional support for each member (Amabile et al. 2001); collaboration theory	▪ Incentives, training, reward structures, etc. (Watson-Manheim and Belanger 2002); (Sclater et al. 2001); communication (Ebrahim et al. 2009); team

2.5.1 Theme 1: Methodology of information exchange

This section introduces a set of methods and principles (referred to here as factors) that can be used for the process of information exchange. In complex design processes, communication activities require a method to ensure successful communication practices. As a result, not applying some or all of these factors can affect the communication channels used. Some studies make a stronger argument about the influence of these factors than others. However, little is known about the consequences of these factors for existing communication channels used in BIM-enabled projects. This section discusses three main factors: Information exchange processes, Information representation, and technical challenges.

Table 2-4: Theme 1: Methodology of information exchange

Themes		Factor	Sub- Factors
Theme #1	Methodology of information exchange	**1. Information Exchange Process** Including: 1. Face-to-Face communication 2. Virtual communication	▪ Exchange information before meeting and regular meeting (Amabile et al. 2001) Collaboration theory LR
			▪ Regular and timely feedback (mentioned in all three literatures) and in, (Amabile et al. 2001); collaboration theory
			▪ Non-verbal communication (ex. sketching) (Homayouni et al. 2010; Dossick and Neff 2011; Sebastian 2011); BIM research
			▪ Shared mutual understanding; (Shannon and Weber); communication
			▪ Misunderstanding (Sclater et al. 2001); communication
			▪ Lack of information flow (Eckert et al. 2001); communication
			▪ Misinterpretation of information (Eckert et al. 2001);(Eckert et al. 2005) communication
			▪ Role of informal communication; (referred to in communication LR as social interaction), improving trust and generating ideas (Ebrahim et al. 2009); team
		2. Information representation (Eckert et al. 2001); (Maier et al. 2008); (Gabriel and Maher 2002); communication	▪ Diversity of Communication Channels (Eckert et al. 2005); (Gabriel and Maher 2002); communication
			▪ Autonomy of task execution (Maier et al. 2008); communication
			▪ Interpretation of representation; real-time interpretation (Eckert et al. 2005) ; communication
		3.Technical noise/ challenges Shannon and Weaver (1949): Communication as a linear process (Maier et al. 2008); communication	▪ Handling technical conflicts (Maier et al. 2008); communication
			▪ Lack of Technical expertise (Powell et al. 2004); (Ebrahim et al. 2009); team
			▪ Lack of technical training and support (Powell et al. 2004); Team (Sclater 2001; Watson-Manheim & Belanger 2002) Communication

2.5.1.1 Information exchange processes

For virtual design teams, information exchange processes may best be supported by understanding the communication practice needs of collaborators (Powell et al. 2004). As a

result, this section presents common methods used for information exchange processes in collaborative environments and common strategies that should be employed to achieve successful communication processes. This helps to identify factors with the potential to influence communication processes, and to what extent these factors may change the mechanism used in communication channels for exchanging information. This section introduces these factors for two information exchange processes: face-to-face communication and virtual communication.

Table 2-5: Theme 1: Information Exchange Process

Theme		Factor	Sub- Factors
Theme #1	Methodology of Information Exchange	**1. Information Exchange Process** Including: 1. Face-to-Face communication 2. Virtual communication	▪ Exchange information before meeting and regular meeting (Amabile et al. 2001); collaboration theory
			▪ Regular and timely feedback (mentioned in all three literatures) and in, (Amabile et al. 2001); collaboration theory
			▪ Non-verbal communication (ex. sketching) (Homayouni et al. 2010; Dossick and Neff 2011; Sebastian 2011) BIM research
			▪ Shared mutual understanding (Shannon and Weber); communication
			▪ Misunderstanding (Sclater et al. 2001); communication
			▪ Lack of information flow (Eckert et al. 2001); communication
			▪ Misinterpretation of information (Eckert et al. 2001); communication
			▪ Role of informal communication (referred to in communication LR as social interaction), improving trust and generating ideas (Ebrahim et al. 2009); team

2.5.1.1.1 Face-to-Face meetings

The influence of face-to-face meetings on communication process performance appears frequently in the communication literature (see Sections 2.4.1.3 and 2.4.2.3), and a strong consensus exists about the importance of face-to-face meetings, both formal and informal. However, more than a strategy for successful work, face-to-face meetings frequently take a primary role in the design profession, particularly with respect to interdependent design activities (Maier et al. 2008; Emmitt and Gorse 2003). Some factors emerged from the three

literature sets that tend to improve the performance of face-to-face meetings, including mutual trust, previous relationships, shared professional language, sending information before meetings, hand sketching, interactivity, and timely feedback.

With respect to the design project context, face-to-face meetings held at early project stages tend to result in improved virtual team performance (Sclater et al 2001). However, from the perspective of Schramm's communication model, the ability of a sender and a receiver to encode or decode a face-to-face meeting greatly depends on the extent of shared common knowledge (see Section 2.4.1.2.3). In turn, the compatibility of backgrounds and skills between team members takes a vital role in fostering mutual understanding (Dainty et al. 2006), perhaps due to the role it plays in providing instant feedback. Furthermore, this type of conversation process can enrich communication content (Powell et al. 2004). However, some factors can reduce the effectiveness of face-to-face meetings, such as unwillingness of members to communicate and incompatibility on knowledge and skills, and can lead to conflicts (see Section 2.5.3.2).

Based on their capacity to address design problems, face-to-face meetings are also regarded as the most common communication method for complex design projects. For example, Gabriel and Maher (2002) examined the effect of various communication channels used in collaborative sessions among architects. Their observations of face-to-face meetings suggested that these conversations were spontaneous, frequently centered on design discussion, and were social in nature. Not surprisingly, these findings tracked those of a similar study by Dossick and Neff (2011), but in this case the sample size was larger (i.e. approximately 70 professionals from different US organizations), compared with Gabriel and Maher's (2002) sample of 52 architectural students. However, Dossick and Neff (2011) observed that the conversations become more constructive when hand sketching techniques were employed. This is perhaps due to the potential of hand sketches to clarify information, which Homayouni et al. (2010: 784) considered part of a *'visual language'* that assists in conversation. In addition, Dossick and Neff (2011) found that Face to Face sessions often lead to additional informal conversations outside of formal meeting sessions. This, in part, can contribute to improved social relationships and increased mutual trust among professionals (see Section 2.4.2.1). However, in Maier et al.'s (2008) study of complex design projects, which aimed to explore the interrelationship of various factors and their effect on design communication processes, the 'face-to-face meeting' factor was largely absent.

To understand the criteria for successful communication processes from the perspective of collaboration theory, Amabile et al. (2001) showed that some procedures, such as sharing information before meetings, planning regular meetings, and sending meeting agendas in advance, facilitated project delivery. These criteria can be essential for team members, even those who collaborate across organizational boundaries. However, in the collaborative research, the hand sketching methods as non-verbal communication in FTF meetings seem to be less frequently used in BIM environments. For example, Sebastian (2011), Dossick and Neff (2011), and Homayouni et al., (2010) all emphasised the role of sketching during meetings to encourage clear communication in collaborative work. However, for the BIM-enabled project that Dossick and Neff (2011) studied, hand sketching was rarely used in face-to-face meetings compared to those of non-BIM team members, who more frequently used sketching as a tool during the conversation. And while Homayouni et al. (2010) and Dossick and Neff (2011) both asserted that hand sketching is a useful communication tool for face-to-face meetings, in the case of BIM projects, the principal objective of these meeting is often to identify problems, rather than solve them.

This leads the researcher to consider the potential of BIM to address these issues, which often revolve around incompatibilities in design drawings. Or, is it possible that in reality, other communication systems are being used, in parallel with the face-to-face system, for example social media? This possibility has not yet been explored in the literature. In relation to this, the literature on team collaboration suggests that using non-verbal communication methods (e.g. body language and eye contact) can improve levels of trust and engender ideas (Ebrahim et al. 2009). In addition, some researchers have found non-verbal communication (e.g. hand sketches, documents, and emails) to be a particularly useful method of exchanging information among professionals from different backgrounds and skills.

This discussion suggests that considerable attention has been given to studying face-to-face meetings for non-BIM projects. However, as stated previously, for many BIM-related projects, the intention of Face-to-Face meetings is to identify problems, not solve them. In this respect, it is useful to consider to what extent face-to-face communication is fundamental for BIM projects. Furthermore, is hand sketching used more or less frequently in Face-to-Face meetings for BIM projects as compared to non-BIM projects? (Q1). The following section introduces factors that influence the information exchange process in virtual environments.

2.5.1.1.2 Virtual communication

Virtual communication among team members is often misunderstood (Sclater, et al. 2001), and this misunderstanding often stems from a number of factors, such as cultural diversity in culture, background, and skills. In communication practice, the information exchange process concerns the interaction between sender and receiver. Thus, both senders and receivers require a similar level of coding skills to facilitate effective communication, particularly in virtual environments. Furthermore, as discussed previously, shared knowledge is essential for success in virtual projects, and its absence can lead to misinterpretation of information (Eckert et al. 2005).

In light of this, from a communication theory perspective, the success of information exchange processes primarily depend on feedback from participants. This feedback is often the most effective tool in reflecting the level of interaction and mutual understanding among communicators. Most communication researchers consider achieving mutual understanding as the main objective (see Section 2.5.1.4). However, two-way feedback processes not only lead to improving mutual understating, but team cohesiveness as well (Amabile et al. 2001). This is often due to the development of mutual trust, particularly for professionals who collaborate across organizational boundaries (Amabile et al. 2001). For example, Sclater et al. (2001) found a positive correlation between the factor 'knowing collaborators in advance' in the success of collaborative communication practices. However, for virtual environments and within asynchronous technology contexts, the authors suggested that collaborators are often easily ignored. However, when synchronous technologies such as video conferencing are used, the authors found conversations to be enhanced (Sclater et al. 2001). In addition, interactive participation is required for both communication processes and collaborative work.

By contrast, an unwillingness of team members to communicate often impedes communication and tends to shift these processes from circular to linear orientations (see Section 2.4.2). From understanding dynamic process of communication from literature and communication theories, it might be that unwillingness of team participants to communicate via new technologies can lead some members to avoid conversations altogether. This is an example of how a factor (i.e. lack of participation) can potentially alter established communication channels. In this case, the question arises as to what extent a lack of interactive participation affects the communication channels used for BIM projects (Q2). Referring to Defleur's requirement of identifying noise within collaborative contexts, each

element involved in a communication environment that has the potential to affect the exchange of information can be considered as 'noise'.

In addition, Eckert et al. (2005) and Maier et al. (2008) reported that a lack of information often leads to communication challenges. Furthermore, Eckert et al. (2005) stated that these challenges most often arise from ambiguities in terms of what designers need to know from others, in a failure to request appropriate information, time constraints, and a lack of feedback. As a result, it is pertinent to ask: what is the impact on communication channels used, of insufficient information between professionals? (Q3). The following section expands upon design representation, diversity of communication channels, interpretation of representations, autonomy of task execution, and technical issues.

2.5.1.2 Information representation

Table 2-6: Theme 1: Information representation

Theme		Factor	Sub- Factors
Theme #1	Methodology of information exchange	**2. Information representation** (Eckert et al. 2001), (Maier et al. 2008), (Gabriel and Maher 2002); communication	▪ Diversity of communication channels (Eckert et al. 2005); (Gabriel and Maher 2002); communication
			▪ Autonomy of task execution (Maier et al. 2008); communication
			▪ Interpretation of representation; real-time interpretation (Eckert et al. 2005) ; communication

Many types of information technologies are used in the design process to support design communication (Eckert et al. 2005). For example, Eckert et al. (2005: 256) identified a number of technologies that support shared distributed design work, such as shared workspace systems (e.g. virtual meeting rooms, intelligent whiteboards) and electronic communication systems (e.g. mail fax systems and video conferences). However, while a range of communication methods are used in the design process, Eckert et al. (2005) reported that for multi-cultural design teams, the preferred communication channel is often face-to-face meetings. The ultimate goal for most designers is to facilitate the process of information exchange using different information representations. However, as the Shannon and Weaver (1949) communication model assumed, if the intent of communication practice is to equally share information among participants, the only obstacle to successful communication is

overcoming any technical disruption (i.e. noise). In addition to the goal of sharing information equally, Eckert et al. (2005) stated that team participants must also possess a common 'encoded knowledge' to understand information. When this diversity of information representation is a reflection of a designer's needs, therefore, interpretation skills become even more essential for a successful communication (see Section 2.5.1).

This discussion leads to the need to understand the role of representation within a design context. For example, according to Gabriel and Maher (2002), digital technologies are often employed not only to document design drawings but also to represent and communicate ideas. However, BIM is used not only for data exchange, but also for sharing data (Nour 2012). In addition, storing information that is accessible at any time of place can change the level of dependence on the feedback of other parties. This lead the researcher to ask if the availability of design information that BIM technology provides has reduced the degree of dependence on email and face-to-face meetings (Q4).

In light of this, insufficient information for design projects can drive designers to use different forms of presentations (i.e. other communication channels). And if a lack of information results in misunderstanding between parties, the reaction of recipients can vary. Alternatively, information alone is often not enough to address the needs of a particular representation, which can lead team members to use alternate communication channels to meet their requirements.

2.5.1.2.1 Diversity of communication channels

Eckert et al. (2005) stated that communication channels are primarily used in the design process to convey various forms for design information. To understanding the influence of the availability of various communication channels in collaborative design approaches, Gabriel and Maher (2002) conducted a qualitative study on three communication types: 1) face-to-face (FTF) meetings; 2) computer-mediated communication using full communication channels (CMCD-a); and 3) computer-mediated communication using limited communication channels (CMCD-b). The results showed that FTF communication tends to be a highly spontaneous social interaction that most frequently concerns design ideas. However, the authors stated that the increased demands of CMCD-a and CMCD-b types tends to decrease both conversation time and discussion of design ideas. They concluded that although there is an accessibility for using full communication channels, time spent in discussion design ideas is

decreased due to the need for controlling the communication processes. However, in a design context, Gabriel and Maher (2002) stated that, “it is more important to ‘see’ what is being discussed rather than ‘watch’ the other person(s) involved in the discussion.” In this regard, the availability of full communication channels does not necessarily lead to improved communication processes, and no clear evidence exists that it can improve design process performance. However, it may be that the need exists for greater control in using a diversity of communication channels (see Section 2.5.1.3). However, while this study does not focus on the effects of diversity of communication channels on communication practices, this finding could help in interpreting why professionals working in both BIM and non-BIM environments tend to limit their use of communication channels. In addition, in the case of BIM projects, It is relevant to explore what communication channels are most commonly used by designers (Q5).

As discussed previously, using a variety of representations can be more beneficial than employing numerous communication channels. Maier et al. (2008) supported this notion, and found that concurrent design activities, diverse forms of representations can help advance the design process. On the other hand, one negative effect of using a diversity of communication channels can be information overload, which leads to the question to what extent this overload influences changes in the use of communication channels (Q6). For example, Watson-Manheim and Belanger (2002) found that employees in some firms can receive between 50 to 100 emails daily. The researchers found several factors that contributed to the issue of information overload, such as lack of trust, as most team members work interdependently. From their view, this factor led to increases in the number of meetings and resulted in negative effects on the communication process, and eventually to the team effectiveness.

However, the question remains, to what communication channels are used for, and why sometimes these channels tend to differ across companies. Watson-Manheim and Belanger (2002) addressed this in a comparative study of two major information technology companies. The researchers collected data from semi-structured interviews with managers and professionals, observations on the physical environment and technology available in each company, and documentation. Study results showed that number of factors can influence the selection of communication channels, including individual preference, urgency, organizational culture, lack of technology training, reward structure, lack of trust, and physical work environment. In terms of preference, the researchers examined both the individual and

organizational level, and found that for Company A, email was the preferred communication channel for most discussions. For the second factor, urgency, study results showed that organizational cultures could affect communication channel choice. For example, while employees of both firms used cell phones and pagers for urgent communication, those in Company A tended to use email and those in Company B used voice mail for less urgent communication. The third factor, lack of technology training, tended to constrain the use of the full range of available channels. For the final factor, work environment, the authors found that period when employee cell phones were not functioning properly led them to use pagers as an alternative communication channel. This lead the researcher to inquire to what extent these factors influence existing communication channels when BIM was used (Q7).

2.5.1.2.2 Interpretation of representations

The diversity of communication channels that technologies such as BIM have offered suggests the need to improve the interpretation skills of design team members. Eckert et al. (2005) reported that the unsuccessful interpretation of design representations often leads to misunderstandings. Consequently, in their view, training design teams in interpretation skills could lead to better use of communication technology and greater ability to discern/understand information from representations (Eckert et al. 2005). However, it seems that little attention has been drawn to the role that real-time interpretation skills play in communication process performance, particularly when using advanced technologies such as BIM. According to Schramm's model, communication can fail due to a lack of shared common knowledge and skills among participants, of which interpretation skills are apart. This is due to the inability of recipients to extract information from representations (Eckert et al. 2005). In addition, the failure of professionals to select appropriate communication channels can also contribute to unsuccessful interpretation. Furthermore, providing insufficient information can affect interpretation (Eckert et al. 2001). This suggests the need to investigate if the lack of real-time interpretation skills of various design representations using the BIM tools, has led to some less skilled professionals to return to using old channels, even though these channels fail to convey information properly? (Q8).

2.5.1.2.3 Autonomy of task execution

With regard to the impact of autonomy of task execution in design representations, which Maier et al. (2008: 58) defined as *'…freedom in one's own decisions and task execution in alignment with one's responsibilities and coordination with others.'* This study revealed four

highly correlated factors in collaborative design, specifically that autonomy of task execution is a core variable that influences collaborative design environments. This result is consistent with Eckert et al.'s (2005) finding that it is necessary to create explicit representations, otherwise, further discussion might be needed it, and design tasks may not be able to be conducted in an independent manner. Maier et al. (2008) also pointed out that representation is strongly related to both availability of product specification information and autonomy of task execution. In sum, improving information representation largely depends on the availability of information about collaborative work and can eventually lead to independent task execution. Therefore, does BIM's facility to represent design information privilege the use of specific communication channels? (Q9)

2.5.1.3 Technical challenges

Table 2-7: Theme 1: Technical challenges

Theme		Factor	Sub-Factor
Theme #1	Methodology of information exchange	**3. Technical noise/ Challenges** Shannon-Weaver model (1949); communication as linear process; (Maier et al. 2008); communication	▪ Handling technical conflicts (Maier et al. 2008); communication
			▪ Technology facilitation (Powell et al. 2004); (Ebrahim et al. 2009); team
			▪ Technical training (Powell et al. 2004); Team (Sclater 2001; Watson-Manheim & Belanger 2002) Communication

When working in a virtual environment, professionals typically use a range of ICTs such as design representations, communication methods, and coordinated design activities (Paré and Dubé 1999). According to Shannon and Weaver's (1949) communication model, technical disruption (i.e. noise) is considered as challenge virtual teams face in communication. In addition, the model states that successful communication processes fundamentally depend on the efficacy of the channel used to transfer information (see Section 2.4.1.2.1). As a result, any technical disruption can affect the flow of information and potential misinterpretation by the receiver. In addition, the technological challenges that Paré and Dubé (1999) identified can influence communication effectiveness. Haywood (1998) defined examples of some technical challenges as 'equipment/software incompatibility or unavailability, infrastructure and equipment complexity, the cost of equipment and communication facilities' (cited in Paré and Dubé, 1999: 481). This suggests the important role technology facilitators play in the

success of virtual teams in managing these challenges. In addition, Maier et al. (2008:56) found that resolving technical conflicts is a factor that influences design communication processes. This is due to lack of the technical training as mention in the study of (Powell et al. 2004; Sclater et al. 2001; Watson-Manheim and Belanger 2002). In addition, technical conflicts not only affect communication process performance, but also collaborative design environments. As a result, technical training can be an effective way to benefit from the information representations that BIM provides. This suggests an investigation into if professionals tend to use some communication channels rather than others to avoid the technical problems (Q10).

Another important issue identified during the pilot study concerns the effect of 'rumour spreading' on the use of communication channels. While findings of Alnaser and Harty's (2016) (see Chapter 4) pilot study support those in the literature that suggest that individual preference, resistance to change, and organizational culture are important in this context, it is worth noting that the factor they termed 'spread of rumour', has not yet been addressed in the communication literature but appears to be an additional influence on communication channel selection in the design process. The preliminary findings suggested that this factor played a role at the decision maker (i.e. manager) level and highlighted the influence of software vendors in offering technologies and therefore communication channels. However, the influence of rumours was more difficult to discern at the individual level, perhaps due to high competition among professionals in BIM work environments. This compels them to continually develop their skills and follow managerial instructions. Consequently, does the rumour play a role in influencing the mechanism used for communication channels? (Q11)

In sum, the process of information exchange among professionals requires a method. Some methods and principles must be established for collaborative environments to facilitate communication, such as Face to Face meetings, hand sketching, prior relationships, mutual trust, interactive participants, common knowledge and skills and two-way feedback. At the same time, some factors repeatedly emerge in the literature regarding their potential to change communication channels, such as individual preference, organizational culture, and lack of training. However, the effect of rumours on communication channels has not yet appeared in the literature.

2.5.2 Theme 2: Collaborative team characteristics

The literature over the last decade has identified a set of common challenges that virtual teams face. These challenges vary in the degree to which they affect team performance, and subsequently on the communication channels teams use. This section is structured around the main categories (i.e. pillars and axes) of collaborative team needs for collaborative teamwork as defined by Amabile et al. (2001): project-related skills and knowledge, collaboration skills, and attitudes and motivation.

Table 2-8: Theme 2: Collaborative Team Characteristics

Theme		Factors	Sub-Factors
Theme #2	Collaborative Team Characteristics	**1. Project relevant skills and knowledge** (Amabile et al. 2001) Collaboration theory	▪ Diversity and Complementarily in skills and common knowledge for team, ▪ Diversity of perspectives, ▪ Share common knowledge. (Amabile et al. 2001); Collaboration theory (Ebrahim et al. 2009; Brennen et al. 2007) ;team
		2. Collaboration skills (Tucker and Abbasi 2012); team (Amabile et al. 2001),Collaboration theory (Gabriel and Maher 2002), communication	▪ Member experience in collaboration (Amabile et al. 2001); Collaboration theory
			▪ leader skill (Amabile et al. 2001) Collaboration theory
			▪ Compatibility of problem-solving (Amabile et al. 2001) Collaboration theory
		3. Attitude and motivation (Amabile et al. 2001) Collaboration theory	▪ Presence of mutual trust and respect (mentioned widely); (Maier et al. 2008) Communication (Amabile et al. 2001) Collaboration theory (Ebrahim et al. 2009); (Brennen et al.2007); team
			▪ Understanding of cultural diversity (Amabile et al. 2001); Collaboration theory
			▪ Reward structure (Ebrahim et al. 2009); team (Watson-Manheim and Belanger 2002); communication

With respect to the first collaboration theory category, project-related skills and knowledge, essential features include: a) diversity and complementarity in skills; b) perspectives; c) and shared knowledge (Amabile et al. 2001). Based on the team theory literature, it appears that the availability of project-related knowledge tends to increase team effectiveness and performance (Brennen et al. 2007). However, the team theory literature also suggests that increasing the level of knowledge about work situations results from improving performance

levels for both communication and monitoring processes (Brennen et al. 2007). Thus, Brennen et al.'s (2007) findings are consistent with collaboration theory as to the importance of providing proper 'knowledge and skills of the project' in collaboration success. In this case, the availability of 'project relevant skills and knowledge' is not sufficient in ensuring collaborative work without effective communication and monitoring. Nevertheless, Amabile et al. (2001) found that cultural diversity across professionals from various organizations resulted in incompatibility in problem-solving styles. Furthermore, this is frequently considered as a driver for unproductive conflict processes (see Section 2.5.3.2).

Using Amabile's theory (2001:419), Simonin (1997) described the second category, collaboration skill, as the *'ability to collaborate effectively with others' that resulted from 'an experience of collaborative relationships.'* Amabile et al. (2001) identified three main features of professional collaborations as leadership skills, experience with collaboration, and compatibility in problem-solving styles. More importantly, the authors found that leadership skills strongly influenced the management of the communication process among professionals. Using technical training as a means to develop the skills of remote managers and virtual teams also appears the literature. For example, Ebrahim et al. (2009) supported the findings of Hertel et al. (2005) that technical training can bolster team cohesiveness and satisfaction. Moreover, Ebrahim et al. (2009) considered technical training as a critical factor for team success, and stated that team members must develop their capabilities in advanced technical skills. Another factor in the literature that affects team skills is the role interactive participants play in influencing the communication process (e.g. Ebrahim et al. 2009). However, the recent proliferation of virtual work has presented challenges that make information exchange dependent on the ability and willingness of remote team members to participate (Ebrahim et al. 2009). In addition, the authors highlighted the essential role virtual team facilitators play in selecting appropriate communication technologies.

The third category of collaborative team characteristics is attitudes and motivation (Amabile et al. 2001). This factor involves the presence of mutual trust and respect, an understanding of cultural diversity, and an open attitude toward diverse people and ideas. With respect to mutual trust and its effect on virtual teams, Brennen et al. (2007) found that increasing the level of mutual trust and commitment among team members can lead to improved task performance and team effectiveness. As discussed previously, this factor is the one of the 12 that Ebrahim et al. (2009) identified that affect virtual team performance. In this case, one of the reasons for the reluctance of collaborators to exchange information using certain

channels most likely depends on either to deficiencies in rewards system or not properly motivating team members. For example, Jarvenpaa and Leidner (1999) identified regular and timely feedback from as critical to establishing trust and commitment among remote teams. However, Brennen et al. (2007) found no direct link with this finding, while Ebrahim et al. (2009) and Paré and Dubé (1999) found that the presence of mutual trust reflects the social dimension among team members. Ebrahim et al. (2009) also asserted that the design process should be considered as early as possible by virtual team to support their effectiveness. And in terms of mutual trust, Ebrahim et al. (2009) concluded that a lack of trust is one of the main challenges virtual teams face, as they rely extensively on computer-mediated communication to perform (Ebrahim et al. 2009). As a result, lack of social interaction can lead to reduced team cohesion and social interaction (Ebrahim et al. 2009). Ebrahim et al. (2009) also supported team motivation and establishing reward structures for virtual teams.

While this section focused on collaborative team characteristics gleaned from three sets of literature, the factor of reluctance to change frequently emerged. In addition, a number of key factors have been discussed in the literature in terms of their potential influence on communication channels, such as lack of mutual trust, insufficient reward structures, lack of shared common knowledge and skills, and lack of communication and monitoring processes. Thus, in terms of these potential effects, it is important to investigate their absence on collaborative teams (Q12). Some of this question is further discussed in terms of leadership and its potential influence on communication channels.

2.5.3 Theme 3: Leadership

Table 2-9: Theme 3: Leadership

Theme		Factors	Sub-Factors
Theme #3	Leadership	**1. Leadership Roles** (Maier et al. 2008); (Fjermestad and Ocker 2007); (Maccoby 2000); (Spaho, 2013); communication (Ebrahim et al. 2009); (Brennen et al. 2007); (Shachaf 2005); team (Amabile et al. 2001); collaboration theory	▪ Appropriate Selective of collaborators, and developing their skill (Amabile et al. 2001); collaboration theory
			▪ Facilitate to share clear understanding about communicators role and responsibilities (Amabile et al. 2001); collaboration theory (Shachaf 2005); communication
			▪ Ensure about the availability of information for the project parties (Maier et al. 2008); communication
			▪ Built trust (Maccoby 2000); (Maier et al. 2008); communication
		2. Conflict process (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory (Watson-Manheim and Belanger 2002); (Emmitt and Gorse 2003); communication	▪ Ineffective leadership (Ebrahim et al. 2009); (Tucker and Abbasi 2012); (Powell et al. 2004); team. (Spaho 2013); communication (Amabile et al. 2001); collaboration theory
			▪ Different culture (Powell et al. 2004); team (Amabile et al. 2001); collaboration theory (Eckert et al. 2005); communication
			▪ Lack of mutual trust (Amabile et al. 2001); collaboration theory
			▪ Lack of mutual understanding DeFleur's communication model (1966); communication
			▪ Variety of perspectives (Eckert et al. 2005); communication (Amabile et al. 2001); collaboration theory
			▪ Clarity of the roles and responsibility of team member according to their expertise and skill (Maier et al. 2008); (Sclater et al. 2001); communication (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory
		3. Institutional support for each member (Amabile et al. 2001); collaboration theory	▪ Such as; Incentives, training, reward structure (Watson-Manheim and Belanger 2002); (Sclater et al. 2001); communication (Ebrahim et al. 2009); team

This section focuses how leadership can influence collaborative work environments in general, and specifically with respect to the selection of communication channels. Mintzberg (1973) defined leadership as a set of roles involved in managing the major functions and tasks of team performance. As with the previous sections, this section was structured around identifying the overlap between factors that emerged from the three sets of literature. The

section classifies these factors by how they may affect the communication channels used from a leadership perspective, and include the role of leaders, conflict processes, and institutional support for collaborators.

2.5.3.1 Leadership Roles

Table 2-10: Theme 3: Leadership Roles

Theme		Factors	Sub-Factors
Theme #3	Leadership	**1. Leadership Roles** (Maier et al. 2008); (Fjermestad and Ocker 2007); (Maccoby 2000); (Spaho, 2013); communication (Ebrahim et al. 2009); (Brennen et al. 2007); (Shachaf 2005); team (Amabile et al. 2001); collaboration theory	▪ Appropriate Selective of collaborators, and developing their skill (Amabile et al. 2001); collaboration theory
			▪ Facilitate to share clear understanding about communicators role and responsibilities (Amabile et al. 2001); collaboration theory (Shachaf 2005); communication
			▪ Ensure about the availability of information for the project parties (Maier et al. 2008); communication
			▪ Built trust (Maccoby 2000); (Maier et al. 2008); communication

Based on the three sets of literature, effective leadership emerged as the key factor in collaborative team performance. To understand the role of leaders from a collaboration theory perspective, Amabile et al. (2001) emphasized the fundamental role leaders play in managing team communication in collaborative contexts. As a social factor (Fjermestad and Ocker 2007), leadership has been widely debated widely in the communication literature (e.g. Maier et al. 2008; Spaho 2013) and in team research (e.g. Brennen et al. 2007; Ebrahim et al. 2009). These three bodies of literature offer factors that reflect the essential roles leaders play in collaborative environments, such as selecting an appropriate collaborators and developing their skills (Amabile et al. 2001); establishing clear understanding about roles and responsibilities (Amabile et al. 2001); ensuring availability of information for project parties (Maier et al. 2008), and building a team trust (Maccoby 2000; Maier et al. 2008). As a result, the absence of these leadership factors can contribute to changes in the selection of communication channels.

To illustrate this point, Amabile et al. theory (2001) indicated that the vital role of a leader in a team environment is to select appropriate collaborators and develop their skills in response

to a project's needs through education and training. The authors stated that another fundamental role of leadership is facilitating a clear understanding of collaborators' roles and responsibilities. Thus, to the authors asserted the importance of defining participant roles and responsibilities at the project outset. This factor frequently appears in the communication literature. For example, Maier et al. (2008) pointed out that establishing clear collaborator roles and responsibilities is one of the main contributors to communication success. In fact, a lack of mutual understanding of these roles designers can result in adverse team performance (Gabriel and Maher 2002).

Another role leadership plays in collaborative environments concerns ensuring the availability of information between the project parties. For example, in the context of communication practice in the design process, Maier et al. (2008) found that this factor facilitated the communication process for teams. Specifically, the authors found information about product specifications, participant needs, roles and responsibilities, and procedures to be essential. As this study demonstrated, improvements in communication processes stemmed from information provision about design products for project teams. In addition, timely feedback can also facilitate the provision of information and lead to improvements in the communication process.

However, while timely feedback from leaders to team members has been shown to be a contributor to communication process success (Ebrahim et al. 2009; Brennen et al. 2007), Brennen et al. (2007) found that monitoring also correlates with feedback and communication. Therefore, increasing the level of leadership monitoring can lead to greater feedback and communication as well as dynamic knowledge of the present situation (Brennen et al. 2007). Brennen et al. (2007:997) defined monitoring as the *'process of tracking the activities through watching and speaking to colleagues,'* and is one of the attributes of effective leaders (Fjermestad and Ocker 2007; Maccoby 2000) that can lead to improved team performance (Brennen et al. 2007). In addition, Fjermestad and Ocker (2007) found that a 'good leader' is one who monitors the exchange of information between project parties by tracking such processes and providing timely feedback. Therefore, if information provision is the role of leaders, the timely provision of information might reflect the quality of their leadership. As a result, it is pertinent to examine if changes in communication channels relates to the lack of leader monitoring in terms of tracking the process of information exchange across these channels (Q13).

Another role of leaders is to build mutual trust among team members. Maier et al. (2008) found a high correlation between mutual trust and two factors: 1) what information parties require, and 2) clarity of roles and responsibilities. This study also indicated that mutual trust is considered a core factor that influences communication practices for design projects and that a link exists between mutual trust and collaboration. This suggests that mutual trust is essential for collaborative work, and that fostering this trust can depend on information provision and clarity of roles and responsibilities. This further emphasises the importance of project leadership in fostering mutual trust.

However, some researchers consider 'mutual trust' to be a reflection of leadership efficacy (Fjermestad and Ocker 2007; Maccoby 2000). This has led some researchers (e.g. Sclater et al. 2001) to consider a lack of the mutual trust among communicators as a barrier to successful communication processes. It seems that trust has considerable influence in terms of communication processes, team dynamics and collective work. Although, this factor has been addressed in the previous section (Theme1: see section 2.5.1.1: the role of face to face meeting towards improving mutual trust), here, it has been presented from a different angle; i.e. the leader's role in conducting a successful information exchange process. Does leadership that increases mutual trust among professionals lead to the use of new communication channels? Also, does the extent of trust among professionals suggest various leadership types, and if so, how might this affect the selection of communication channels? (Q14)

Several management strategies have been proposed in the literature to increase levels of trust. For example, Sclater et al. (2001) and Paré and Dubé (1999) found that friendships and trust can develop when collaborators know each other in advance. Brennen et al.'s (2007) causal map model shows clear evidence of the influential role mutual trust plays in facilitating monitoring processes. Study results showed that increased trust resulted in greater team identity, which Maier et al. (2008:57) defined as the *'strength of belonging to the team.'* As a result, the presence of trust can strengthen team dynamics and likely lead to increased levels of monitoring (Brennen et al. 2007). In addition, Sclater et al. (2001) found that participants who know each other can better communicate and express their thoughts more freely than those who do not. Moreover, Powell et al. (2004) found that holding advance Face to Face meetings resulted in a higher level of trust and effectiveness among team members.

This leads to the previous discussion on information exchange methodology (see Section 2.5.1) in terms of the role Face-to-Face communication plays at the inception of projects.

Furthermore, while this strategy is traditional, it has proven to be essential to the BIM work environment. This suggests a question: What role can team leaders play in strengthening mutual trust between professionals? (Q15)

After reviewing these factors and their potential effects in a collaborative context, it appears that the success of communication and team performance stems from effective leadership. This suggests that effective leadership can lead to successful communication processes and team performance. In light of this, the researcher was motivated to review the literature on leadership in order to investigate how to improve leadership effectiveness for virtual teams.. Shachaf (2005) addressed this question by suggesting four dimensions for improving leadership effectiveness: communication, understanding, role clarity, and leadership attitude. For example, the role of leader in a communication process is to provide ample feedback, actively engage in regular and timely communication, and clarify tasks (Shachaf 2005). However, in terms of understanding this role, Shachaf (2005) stated that leaders could also appreciate team members' opinions and suggestions, address their concerns, and form close relationships with them. While the clarity of team member roles is an important and consistent factor among scholars in terms of identifying their responsibilities. In terms of team leader attitude, Shachaf (2005) stated that leaders should be 'assertive rather than too bossy.' Along these lines, Maccoby (2000) listed four functions of good leadership as selecting talent, motivation, coaching and building trust. In addition, Fjermestad and Ocker (2007), found that effective teams have effective leaders based on their results that high-performance teams communicated more regarding design alternatives. The researchers collected data on eight graduate student teams that used design information software and communicated via one asynchronous web-based channel. However, this study investigated the number and length of messages that the team received as a metric for measuring effective leadership, and studied students with only limited experience in a virtual communication environment with constrained communication channel use. However, the results of Fjermestad and Ocker's (2007) study were consistent with those of Brennen et al.'s (2007) team research and Maier et al.'s (2008) communication research in that if information provision is essential for information exchange it is most important to monitoring this exchange to foster successful communication practices.

This section explored the potential roles of leaders based on a review of the three sets of literature. In sum, this review suggests that effective leadership can lead to more successful communication practices and team performance. However, building mutual trust among

team members seems to be a more fundamental leadership role due to its influence on collaborative work performance. This section also posed some empirical questions that were later tested in BIM environments. The following section expands on two additional factors: conflict process and Institutional support.

2.5.3.2 Conflict processes

Table 2-11: Theme 3: Conflict processes

Theme		Factors	Sub-Factor
Theme #3	Leadership	**2. Conflict process** (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory (Watson-Manheim and Belanger 2002); (Emmitt and Gorse 2003); communication	▪ Ineffective leadership (Ebrahim et al. 2009); (Tucker and Abbasi 2012); (Powell et al. 2004); team. (Spaho 2013); communication (Amabile et al. 2001); collaboration theory
			▪ Different culture (Powell et al. 2004); team (Amabile et al. 2001); collaboration theory (Eckert et al. 2005); communication
			▪ Lack of mutual trust (see Section 2.4.1) (Amabile et al. 2001); collaboration theory
			▪ Lack of mutual understanding (see Section 2.4.1) DeFleur's communication model (1966); communication
			▪ Variety of perspectives (Eckert et al. 2005); communication (Amabile et al. 2001); collaboration theory
			▪ Clarity of the roles and responsibility of team member according to their expertise and skill (Maier et al. 2008); (Sclater et al. 2001); communication (Tucker and Abbasi 2012); team (Amabile et al. 2001); collaboration theory

Several definitions of conflict appear in the literature. McGrath (1984) defined *conflict* as *'disagreements between individuals regarding their preferences, viewpoints, and positions,'* and Rahim (2002:207) described it as *' an interactive process manifested in incompatibility, disagreement, or dissonance within or between social entities (individual groups, organizations, etc).*' Conflict is common place in any organization, and practical experience demonstrates that there is *'no communication without conflict'* (Spaho 2013:10). As a result, understanding conflict processes and their consequences is a prerequisite for collaborative design success. While several causes of conflict exist in the literature, for the purposes of this study the researcher focused on factors that emerged from the three sets of reviewed literature in order to investigate to what extent these factors can contribute to changes in

communication channels. This section discusses the conflict process and its sources, including ineffective leadership, diversity of team culture and perspectives, and lack of trust and mutual understanding.

An ongoing debate exists in the literature about whether the conflict process positively or negatively affects team performance. For example, in the context of the collaborative design environment, conflict process can lead either to negative or positive outcomes (Spaho 2013; Amabile et al. 2001). In terms of positive outcomes, Amabile et al. (2001) found that the conflict process that ensues when collaborators discuss ideas led to evolution and advancement in projects. In addition, Sclater et al. (2001) found that conflicts among students with diverse skills and backgrounds ultimately had a positive affect on their projects. However, Amabile et al. (2001) demonstrated that conflict processes that stemmed from a lack of understating of cultural differences and lack of clarity about team member roles and responsibilities led to negative outcomes. In addition, Maier et al. (2008) showed that a lack of knowledge about participant roles and responsibilities can lead to conflict for design teams. In the context of collaborative theory, collaboration processes appear to improve when team members have a clear understanding of their roles, which is an important determinant for successful collaboration processes (Amabile et al. 2001).

However, other aspects of conflict have emerged in communication theory models. Such conflicts stemmed from a lack of shared understanding among different professionals due to the incompatibility of coding skills or lack of mutual trust (see Section 2.4.1). Furthermore, 'noise' elements can also contribute to generating conflict (see Section 2.4.1.4). In addition, most communication research asserts that these factors can impede successful communication practices. This finding is consistent Fjermestad and Ocker (2007), who indicated that conflict can lead to poor team performance.

Either positive or negative conflicts can influence collaboration process success. As a result, managing conflict resolution processes is important to the professional collaborative environments (Amabile et al. 2001). The collaboration theory and literature categorises the conflict resolution process as one determinant of successful collaboration, such as Amabile et al. (2001) discussion of the impact of conflict on team performance.

With respect to the role a leader's skills and experience plays in managing conflict processes, it appears from Amabile et al. (2001) that leaders play a critical role in managing conflict. This finding is corroborated by most of the relevant literature (e.g. Spaho 2013). Furthermore,

Ebrahim et al. (2009); and Tucker and Abbasi (2012) found that for virtual teams, leadership skills and experience' play a fundamental role in managing conflict. In addition, Amabile et al. (2001) recognized leadership as the one of the main factors in supporting collaborative work. Moreover, Sclater et al. (2001) indicated that effective leaders possess skills, knowledge, and experience in guiding participants towards a common goal. This suggests an inquiry into how leadership skills and experience can affect the selection of communication channels used in BIM–related projects (Q16).

As discussed previously, the communication literature revealed potential factors and their consequences in terms of the role leadership plays in managing this conflict processes. Based on the team literature and the role cultural differences can play in the conflict process, Powell et al. (2004); and Tucker and Abbasi (2012) conducted reviews of a virtual team studies. For example, Powell et al. (2004) found that conflict typically occurred when teams are composed of members from diverse cultures, skills and backgrounds and emphasized the importance of conflict management for virtual teams. The researchers also stated that cultural diversity is common for virtual teams and can impede their level of coordination and communication. Furthermore, as for the impact of cultural differences, Tucker and Abbasi (2012) found that this factor can have an adverse effect on team performance. Therefore, in a virtual team context, teaching team members accept cultural differences could be significant (Tucker and Abbasi 2012). In addition, collaboration theory suggests that understanding cultural differences is a collaboration skill that is important to successful collaboration processes (Amabile et al. 2001). Sclater et al. (2001: 251) found that organizations should introduce not only a *'culture of opening exchange for the knowledge and ideas'* but also using incentives culture to support successful communication processes. Incentives can also be used to resolve conflict processes as strategies to foster information exchange. For example, Amabile et al. (2001) considered incentives as essential for successful collaborative teams. Another applied strategy that has been used to resolve conflict is the Face-to-Face meeting. For example, in the context of communication research, Eckert et al. (2005) indicated that Face-to-Face meetings can help resolve conflicts concerning project elements. However, Emmitt and Gorse (2003) maintained that conflict resolution remains more problematic for teams that include different firms.

Other sources of conflict within collaborative work include a diversity of perspectives and the absence of common reference information. In fact, a diversity of perspectives represents one of the primary sources of team conflict (Eckert et al. 2005). For example, negative (i.e.

unproductive) conflict processes can emerge due to the incompatibilities of the problem-solving styles of team members (Amabile et al. 2001). Furthermore, many team studies, such as Powell et al. (2004), show that the absence of common references can lead to conflict, particularly among multi-disciplinary design teams that cross organizational boundaries. In this context, *shared common reference* refers to shared materials and equipment, standard dimensions, and terminology that is used in the design process (Powell et al. 2004).

After reviewing the various aspects of the conflict process from the three sets of literature, it appears that conflict processes are influenced by a number of factors, such as lack of leadership skills and experience, lack of mutual trust and understanding, lack of roles and responsibilities, lack of incentives, and diversity of team culture and perspectives. Therefore, one remaining question concerns how these factors might affect the communication channels used in BIM projects. While many researchers have found conflict to be beneficial, and others have deemed it detrimental, in both cases the role of the leader is fundamental to managing conflict. This leads to an additional question: What is the effect of trust and conflict among professionals on communication channels they use (Q17)?

2.5.3.3 Institutional support for team members

Table 2-12: Theme 3: Leadership and institutional support for team members

Theme		Factors	Sub-Factors
Theme #3	Leadership	3. **Institutional support for each member** (Amabile et al. 2001); collaboration theory	▪ Incentives, training, reward structure (Watson-Manheim and Belanger 2002); (Sclater et al. 2001); communication (Ebrahim et al. 2009); team

This section focuses on how organizations can support their teams. Amabile et al. (2001: 420) defined institutional support as *the 'degree of support that each participant receives from their own institution'.* This factor has been categorized by in the literature as a primary characteristic of successful collaborative environments. In the communication literature, this factor corresponds to Deflour's communication theoretical model in terms of the influence of 'noise' elements, which can arise from environmental contexts. However, despite the significant effect of institutional context on communication success, Amabile et al. (2001) found that an examination of institutional support for collaborators is largely likely absent

from the collaboration literature. Furthermore, the level of value and support that collaborators receive from their institutions can also affect the time and resources they devote to their projects (Amabile et al. 2001). This suggests an examination of the potential types of support that institutions could provide to their team members. Moreover, to what extent might institutional support motivate BIM professionals to use alternate communication channels (Q18)?

The literature addressed the first part of this question. For example, Watson-Manheim and Belanger (2002) reported that much attention has been paid to the role of incentives in the communication process. In this regard, using incentives appears to be a motivational practice for sharing and exchanging knowledge. This finding is also supported in the team literature, as Ebrahim et al. (2009) found reward structures to be one factor that strongly contributes to the success of virtual teams. As a result, one measure of effective leadership could be success in identifying reward structures appropriate for team needs and sufficiently motivating participants. Compared with other collaborative environments, a lack of trust seems more common in the design process context, largely due to its general diversity of backgrounds and cultures. This lead the researcher to ask if reward structures can sufficiently motivate professionals to use new types of communication channels (Q19).

2.6 Summary

This section reviewed the factors and components that constitute the complex collaborative communication process practised by professionals. This chapter categorized the potential implication of using BIM on communication channels into three themes: (1) methodology of information exchange; (2) collaborative team characteristics; and (3) leadership. Based on this review, it is clear that using BIM has largely changed the nature of face-to-face meetings from a focus on solving problems to one of identifying problems (e.g. Dossick and Neff 2011). In addition, a common finding in the literature is that individual preference and organizational culture are the main drivers for communication channels selection. However, the review also revealed that little attention has been paid to how leadership roles might contribute to this change. Building on the concepts discussed in this chapter, this section posed questions that formed the basis for the interview protocols used in the pilot study. Chapter 3 discusses the research strategy and methods employed to collect the necessary study data.

Chapter 3

Research Strategy and Methods

Chapter 3. Research Strategy and Methods

3.1 Introduction

This chapter outlines the research strategy and methods applied in this study. The chapter first presents a diagram[1] (see Figure 3-1) of the research process stages that were followed to address the question of 'what' happened in the communication channels and 'why.' It follows with Table 3-1, which summarises these steps and addresses the research methods used to collect the qualitative case study data to achieve the research aim.

The chapter presents the research employed in this study in two different sequences. The first sequence concerns a pilot study that was conducted to refine the initial research questions derived from the literature and to identify relevant factors (see Chapter 2). The second presents the main study, and outlines both the data collection techniques and the data analysis process. The chapter concludes with a discussion of research limitations and the ethics strategies followed throughout study.

[1] While developing the research method, the researcher used this diagram as a visual tool to gain a deeper understanding of the shape of this research.

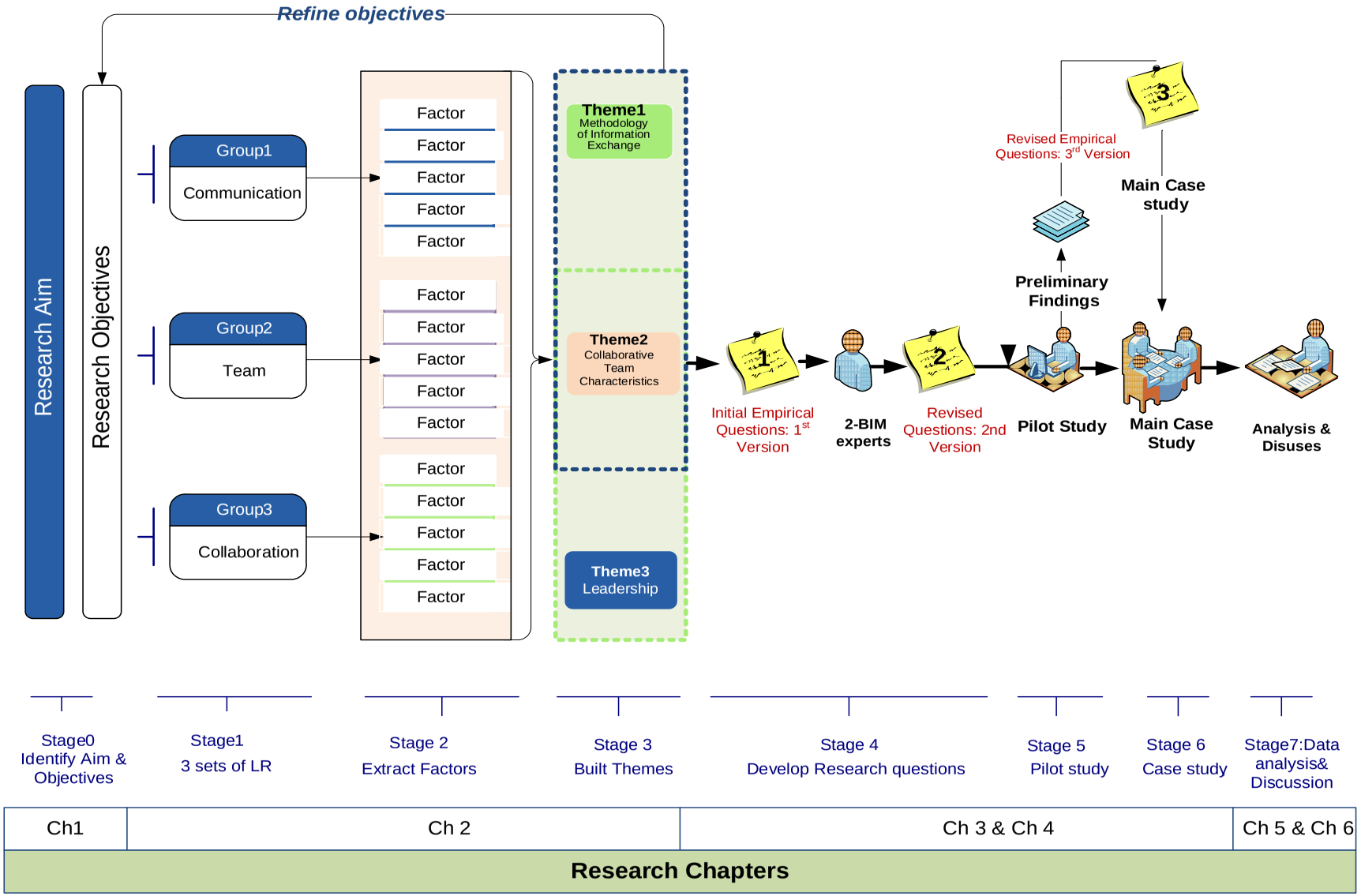

Figure 3-1: The research design

Table 3-1: Summary of research stages

Research Stage	Description	Chapter
Stage 0	Identify research aim and objectives.	1
Stage 1	Review literature in three core areas: (1) communication processes, (2) teamwork, and (3) collaboration. In addition, review relevant theory, including communication theory (from linear to interaction processes), team theory, and cross-profession collaboration theory.	2
Stage 2	Identify potential influential factors from these three areas and explore the definitions of these factors in the literature. Importantly, selection of these factors was based on their effect on process performance with respect to the communication, team, and collaboration literature as well as relevant theory.	
Stage 3	Group the potential influential factors into themes. This categorisation and comparison process helped to develop the analytical framework of this research. The final step was to classify these factors into three main themes (i.e. methodology of information exchange, collaborative team characteristics and leadership) with corresponding sub-factors. Importantly, any overlap that emerged across these themes and factors further assisted in developing the research questions for the pilot study with respect to how these factors may affect changes in communication channels	
Stage 4	Develop the initial research questions (i.e. first version) based on Stage 3. These questions were tested with two BIM technology professionals with over four years of experience. This process led to revisions in the research questions (i.e. the second version) that were used in the pilot study.	
Stage 5	Conduct pilot study on four BIM organisations in Saudi Arabia by using four telephone interviews and eight email questionnaires. This step led to further revisions of the research questions (i.e. third version) and helped with the selection of data collection techniques and the case study used for the main study. Firm Pc1 was selected as the case study (see Ch 4, Figure 4-1).	3 and 4
Stage 6	Collect case study research data by interviewing 22 professionals from different departments within Pc1 (see Chapter 3, Table 3-3).	
Stage 7	Analyse empirical research data and discuss findings.	5 and 6

3.2 Research Strategy and Methods

This section outlines the research strategy and methods that were adopted to address the research question and study objectives. It begins by describing the pilot study and follows with a discussion of the main case study research. In addition, this section justifies the selection of the data collection techniques used in this study and describes the data analysis techniques.

3.2.1 Pilot study

As discussed previously, this study focuses on if and how the adoption of BIM affects the communication channels used in design projects. To meet the aim of this research, a pilot study was first conducted to gain a deeper understanding of the dimensions of the research problem, such as determining the specific design team and selecting an appropriate case study (i.e. comparing BIM and non-BIM processes either between firms, projects, or teams). As Yin (2009) asserted, a pilot study should assist and reflect the main study, but in a smaller version.

As Collins (2010: 167) stated about on the purpose of pilot studies, *'Pilot studies can inform us about the best research process and occasionally about likely outcomes.*' In addition, these studies can help to *'revise the research data collection plan after understanding the data context with their devoted resources, and the proper procedures to be followed'* (Yin 2009: 92). Furthermore, using a pilot study as research procedure can help to support the validity of research findings (Yin 2009), and can test interview questions for clarity or appropriateness in a research context (Bryman 2012), which can improve the quality of those questions (Yin 2009). Another advantage of conducting a pilot study is to develop a researcher's skills in conducting interviews and forming relationship with practitioners and experts. In terms of this research, the pilot study also clarified certain issues in terms of accessibility to respondents and if the most appropriate approach would be to compare across projects, teams or firms.

After reviewing the literature in communication research (see Chapter 2), four broad data collection methods emerged that were appropriate for this research: semi-structured interview (e.g. Watson-Manheim and Belanger 2002; Eckert et al. 2005; Maier et al. 2009; Daim et al. 2012; Maier et al. 2008; Chiu and Cheng-kung 2002); questionnaire (e.g. Kivimäki et al. 2000; Eckert et al. 2005; Chiu and Cheng-kung 2002); experiment (e.g. Gabriel and

Maher 2002; Chiu 2002; Fjermestad and Ocker 2007; Ocker and Fjermestad 2008); and observation (e.g. Watson-Manheim and Belanger 2002; Eckert et al. 2005; Sclater et al 2001; Senescu and Haymaker 2013). The fourth technique, observation, was excluded from the pilot due to the distance of the researcher from the participants under study.

Finally, the overarching aim of conducting this pilot study was to address the research questions. In addition to assisting the researcher, conducting this preliminary step helped in selecting the appropriate case study for this dissertation. As a result, the organisation 'Pc1' was selected as the primary case study for this research.

The pilot study was designed to follow a sequential explanatory strategy that employed a mixed method data collection approach. For the first stage, quantitative data collection and analysis methods were applied that helped to refine the initial interview questions. In addition, a triangulation data strategy was employed for each potential case organization. The rationale for conducting the pilot study as an initial research procedure was to support the validity of the research findings (Yin 2009), and it facilitated testing the initial interview questions (Bryman 2012) and improved their quality (Yin 2009). As Figure 3-1 showed, it is worth noting that the initial interview questions were drawn from the literature and tested with two BIM professionals with more than four years of experience. For the pilot study, the triangulation method mixed data techniques for all potential cases, and was applied to ensure that the resultant findings were accurate (Saunders et al. 2009). Additional advantages of conducting the pilot study were that it provided an initial perception of the BIM context and an understanding of the extent to which BIM has been implemented in the design sector.

Before collecting data, the researcher contacted all participants as a priori confirmation of their abilities and participation in this study. Data were collected between June and August 2015 from three organisations (Pc1, Pc2 and Pc3) and one participant from the Saudi Ministry of Health (Pc4). To capture both quantitative and qualitative data, the proposed pilot study questions were divided into two sections: a questionnaire (see Appendix 1) and interview questions (see Appendix 2). The semi-structured interviews were conducted with an architect, BIM coordinators, and project managers across the four organisations.

Eight professionals completed the questionnaires, and semi-structured interviews were conducted with four of them (see Figure 3-2). The goal was to capture a range of viewpoints from professionals experienced with BIM-enabled projects, and the interviews were conducted at various intervals. The interview questions were derived from the questionnaire

responses, which provided some insight into the types of factors involved in this study. This step helped to refine the final interview questions (Creswell 2009) and further frame the contributing factors. The two main objectives of the questionnaires were: 1) to identify the types of communication channels used; 2) to measure the frequency of their use within a BIM context, and 3) narrow the focus to the most likely influential factors.

Table 3-2: Data collection techniques for the pilot study

Data collection technique	Data type	Sample size	Tools	Data analysis technique
First method	Quantitative data: Questionnaires	8	Email	Manual
Second method	Qualitative data: In-person interviews	4	Interview by telephone (Skype)	Thematic analysis (manual)

Overall, the pilot study was an essential step in clarifying the unit of analysis and training the researcher in interview skills (Bryman 2012). In addition, it helped the researcher to understand the extent to which BIM has been implemented in design sectors to date. Moreover, such pilot assisted in saving time and costs and improved the researcher's perception regarding the role of BIM in the design process.

3.2.2 Main study

This section describes the case study strategy adopted for this research and explains the selection of the semi-structured interview as its main data collection method. In addition, this section clarifies why observation was excluded from this study, despite its broad use in the literature. Table 3-3 lists the job title and interview duration for all 22 interviewees. Finally, this section describes the thematic analysis method used for analysing the qualitative data that were collected.

3.2.2.1 Case study strategy

To meet the purpose of this study, the case study approach can afford a rich understanding of a research context (Morris and Wood 1991). Robson (2002: 178) defined a case study as,

'…a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence.' In

addition, Saunders et al. (2009) asserted that case study research can provide considerable ability in answering research questions of what and why, and that this strategy is most often used in exploratory research (Saunders et al. 2009). For this dissertation, while two methods were initially proposed to collect data, the interview technique was the only method employed. This method was selected because it corresponded to the case context, which will be discussed in the following sub-sections. In addition, the interview technique has been employed widely in the literature for both communication research and BIM research (see Chapter 2, Table 2.2)

Yin (2009) listed four case study strategies: single case, multiple cases, holistic case, and embedded case. As this dissertation collected data on a single case study, the question arose as to the need to ensure that the findings of one case are consistent with others (Saunders et al. 2009). If so, an examination of multiple cases might be preferable to investigating a single case (Yin 2009), particularly if there is a need to generalise study findings (Saunders et al. 2009). This notion generated a new line of inquiry: Does this study need to generalize its results? Based on the research limitations, this dissertation focuses on understanding the phenomenon of changes that occur in the use of communication channels within a social and collaborative context after implementing a new technology (i.e. BIM).

For this research, a case study approach was adopted to address the research question and the researcher collected qualitative data. In line with achieving this aim, the ethnographic research literature offers another option to collect qualitative data (Creswell 2009). However, this approach was excluded due to limitations related to the research context (see Section 3.4). In this respect, a case study afforded several advantages for this study, as it helped the researcher investigate communication processes among BIM users within a complex social context. In addition, as the researcher comes from an academic background, it helped to provide a visual understanding of the environment in which the data were collected, such as the layout of the workplace and equipment, arrangement of the departments and the physical relationships between team members and their managers. Furthermore, this approach afforded the opportunity to observe the actors interact in various settings and their informal conversations as well as building friendships with the people in the organisation. On the other hand, after experiencing the physical work environment of the case study organisation, a line of inquiry emerged that needed to be clarified to understand the participants' views and their behaviour in depth.

Based on this discussion, understanding the context of the case study was important in order to fully explore the effect of using BIM on communication channels. From a procedural perspective, this strategy also helped to support the selection the of data collection method and refine the interview questions. In addition, this helped to determine the scope of the study, as due to the interdependent nature of architectural work it can be difficult to separate one department from others. This, in turn, led to expanding the research sample range from BIM users in the design department to those in other departments within the case study organization (Mc1).

3.2.2.2 Data collection: Interview

For this study, the interview method assisted in investigating not only 'why' a particular process happens (Yin 2009), but also afforded access to other key respondents. Moreover, Yin (2009) argued that in certain situations, an interviewee may suggest another person to interview or a document to review as additional sources of information. It is worth mentioning that the research respondents suggested two additional respondents who had recently moved to another organisation: the BIM manager and the BIM coordinator for the main case (Mc1).

Based on the literature review, employing a qualitative data collection method was the main route in addressing the study aim, and was achieved by conducting semi-structured interviews (Yin 2009). Observation is another method for collecting qualitative BIM research data, but this technique was excluded after the researcher arrived in the field (i.e. organisation). This was due to two reasons: 1) a lack of the ongoing BIM projects to observe at that time; and 2) the nature of Saudi society, which makes it difficult for this technique to be applied, particularly for female researchers.

Along with being considered as a common data collection technique, conducting semi-structured interviews provides flexibility to the conversation (Saunders et al. 2009). The author interpreted this flexibility in several ways, such as the opportunity to change the sequence of interview questions based on the course of the dialogue, the potential for adding questions based on the need for further exploration, and that this *'…may omit some questions in particular interviews*' (Saunders et al. 2009:320). Additionally, semi-structured interview data '…are likely to be used not only to reveal and understand the 'what' and the 'how' but also to place more emphasis on exploring the 'why'' (Saunders et al. 2009:321). For

that reason, the interviews for this study were conducted in person and via telephone. The single exception to this process is that one interview (A22, Mc1) was conducted electronically, was not used because the responses were characterised by brief answers that did not provide sufficient interpretation of the questions.

In addition to the interview method, Creswell (2009) described a fourth qualitative data collection type: gathering supplementary qualitative visual materials. According to the author, these *'…data may take the form of photographs, art objects, videotapes, or any forms of sound'* (Creswell 2009:180). For this study, the researcher collected visual data, including images of the participants' workplace and their meeting rooms and written materials such as A0 drawing sheets and examples of hand sketches.

Prior to collecting data, the researcher emailed the case study (Mc1) organisation's management as a priori confirmation to ensure their abilities and willingness to participate in this study and to arrange an appropriate time to conduct fieldwork. In addition, to secure approval to collect data at the organisation, the researcher contacted the Saudi Arabian cultural bureau in London, and her local sponsor, The Royal Commission for Jubail and Yanbu (RCJY) in Saudi Arabia. Importantly, four months passed between receiving confirmation from the organisation and the local sponsor until the researcher began to collect data. Data collection ran from March to May 2016 with interviews of 22 participants ranging from designers, architects, managers, BIM managers, BIM coordinators, project managers, department managers and IT staff (see Table 3-3). However, one IT respondent was later excluded from the study during the data analysis phase, as the interview questions were not designed for this type of profession. The majority of the interviews lasted between 40-60 minutes, save two, which lasted up to two hours. A total of 19:51:11 hours of interview material were collected.

With respect to the interview protocol, this study followed Creswell's (2009) recommendations. The interview process followed several steps: 1) asking the interviewee's name, years of experience and profession; 2) posing the primary and supplementary questions; 3) requesting suggestions for additional participants; and 4) thanking the participants for their time and support (see Appendix 3).

Table 3-3: Research participant list

Job Title	Interview duration
Design Manager	*01:06:08*
General Manager	*00:41:05*
Architectural Department Director	*00:46:42*
Quality Department Manager	*01:27:46*
BIM Manager	*01:52:00*
BIM Coordinator	*02:00:00*
Senior Architect	*00:46:41*
Architect	*00:49:03*
Design Architect	*00:26:14*
Design Architect	*00:51:25*
Design Architect	*01:14:05*
Sustainability Department Manager	*00:49:58*
Structural Engineer	*00:45:33*
Senior Electrical Engineer	*00:28:56*
Senior Project Manager	*01:21:17*
Senior Architect	*00:62:00*
Design Architect	*00:56:18*
Interior Architect	*00:47:00*
Architect	*00:58:29*
IT staff member	*00:10:00*
Design Architect	*00:30:31*
Project Manager	*518 words*

The Face to Face interviews were conducted in a meeting room and used two hard copies of the list of questions (one for the interviewer and one for the respondent) in order to give the interviewees time to consider and pose their own questions before and during the interview sessions. The researcher audio taped the interviews and made notes that were immediately uploaded to a cloud storage application (i.e. Dropbox) as a backup. The main reasons for taking notes was to help capture the basic elements pertinent to the factors, communication channel types, and verbal and non-verbal behaviour. The note-taking process was used for later reference and to record a summary of the main points captured in each interview. This, in turn, facilitated the analysis process and improved subsequent interviews, as the researcher was able to reflect on these notes for subsequent interviews. It is worth mentioning that although the interview questions were initially drawn from the literature and tested in the pilot study, for the main study, the director of the organisation department

asked the researcher to test these questions by first interviewing him, which was recorded. The rationale for this request was that the director wanted to ensure the clarity of the interview questions and to select BIM users as research participants. The director offered several suggestions for changing these questions, such as replacing the word 'philosophy' with 'concept,' and helped with participant selection based on the interview questions and aim of this research. However, some identified interviewees declined to participate.

3.3 Case study analysis strategy and method: Thematic analysis

Thematic analysis is *'…a method for identifying, analysing, and reporting patterns (themes) within the data'* (Braun, V. and Clarke 2006:6). Moreover, the authors stated that thematic analysis helps organise and describe textual data in detail. This analysis process is not linear, but rather *'…a recursive process, where you move back and forth as needed, throughout the phases'* (Braun, V. and Clarke 2006:16). Furthermore, Ely et al. (2005:16) stated that this *'process evolves over time.'* This section presents the thematic analysis process used in this study.

Phase 1: Qualitative data transcription. The data collection period lasted three months, followed by another three months to transcribe the audio interviews using Microsoft Word. Interviews were conducted to collect this data and the interviewer transcribed these interviews and double checked them against the recordings. This process improved the accuracy of the text and the researcher's familiarity with the data set (Braun, V. and Clarke 2006). In addition, this iterative process of reading and transcribing the data suggested potential research themes (Braun, V. and Clarke 2006) and influential factors. Moreover, it served to prepare and organise the 22 interviews for the analysis process.

Phase 2: Selection of an appropriate qualitative data analysis program. As the interviews were conducted in Arabic, their initial transcription was also in Arabic. As a result, it was necessary to select textual analysis software that supports Arabic. Creswell (2009) suggests several applications for qualitative data analysis, and the researcher reviewed these suggestions before deciding to hand code the textual data after its initial analysis. A review of textual analysis software showed that only *MAXqda*, a German program, supports the Arabic language.

Phase 3: The coding process. This phase involved a series of steps as follows (see Figure 3-6).

- ***1st step***: Prior the coding process, several readings of the interview data were carried out in order to *'…obtain a general sense of the information and to reflect on its overall meaning'* (Creswell 2009:185). This step helped to establish a general sense of whether or not communication channels were changed and the potential drivers (i.e. factors) of these changes. Moreover, it allowed the researcher to identify the types of communication channels used within the BIM work environments, and to generate a list of initial codes.

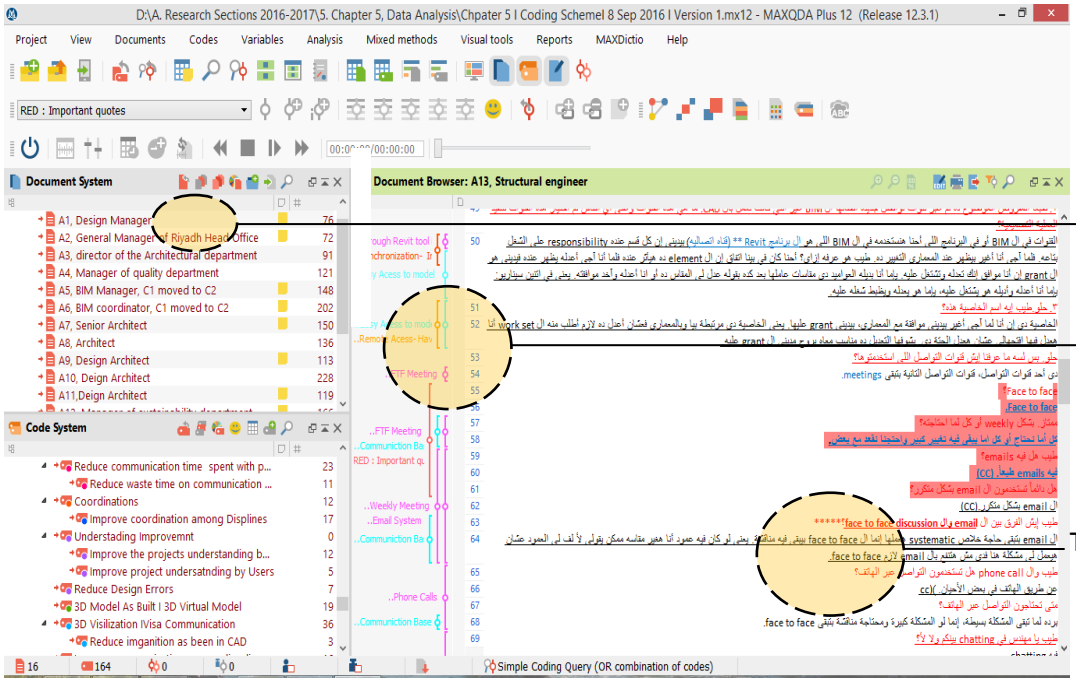

Figure 3-2: Screen shot of the MAXqda interface showing the initial coding before moving to hand coding

As stated above, the coding process was carried out using the analysis software *MAXqda* (see Figure 3-2). Each textual data set was read separately and summarised either as text or a diagram, which provided a review of the emergent ideas for each interview. Although Creswell (2009:188) stated that using qualitative analysis software is '*…an efficient means for storing and locating qualitative data*,' during the coding process the data for 16 interviews were in danger of being lost due to the unknown program failure. As a result, the researcher continued to code the transcripts manually (i.e. hand coding), and kept soft and hard copies of all transcripts.

- ***2nd step*:** All transcriptions were printed, labelled by paragraph, and compared across the entire data set. This process resulted in the identification of the initial code list (i.e.

the first stage in developing the research code scheme). According to Creswell (2009:187), coding textual data involves a process that, *'…the reader expected to find, based on past literature and common sense.'* In addition, this process codes surprising and unusual data and data that addresses the theoretical perspectives involved.

- ***3rd step***: The initial list of codes was compared with the results of the pilot study. In this step, the empirical data for the pilot study was been reviewed in terms of how the data were coded, analysed and discussed (see Figure 3-3). Furthermore, this step afforded the opportunity to identify differences and similarities in the coded data between the pilot study and the main study, which in turn helped to develop the second coding scheme (i.e. the 2nd stage of coding development). In this regard, one of the most important results of this step was the emergence of a new sub-code (i.e.

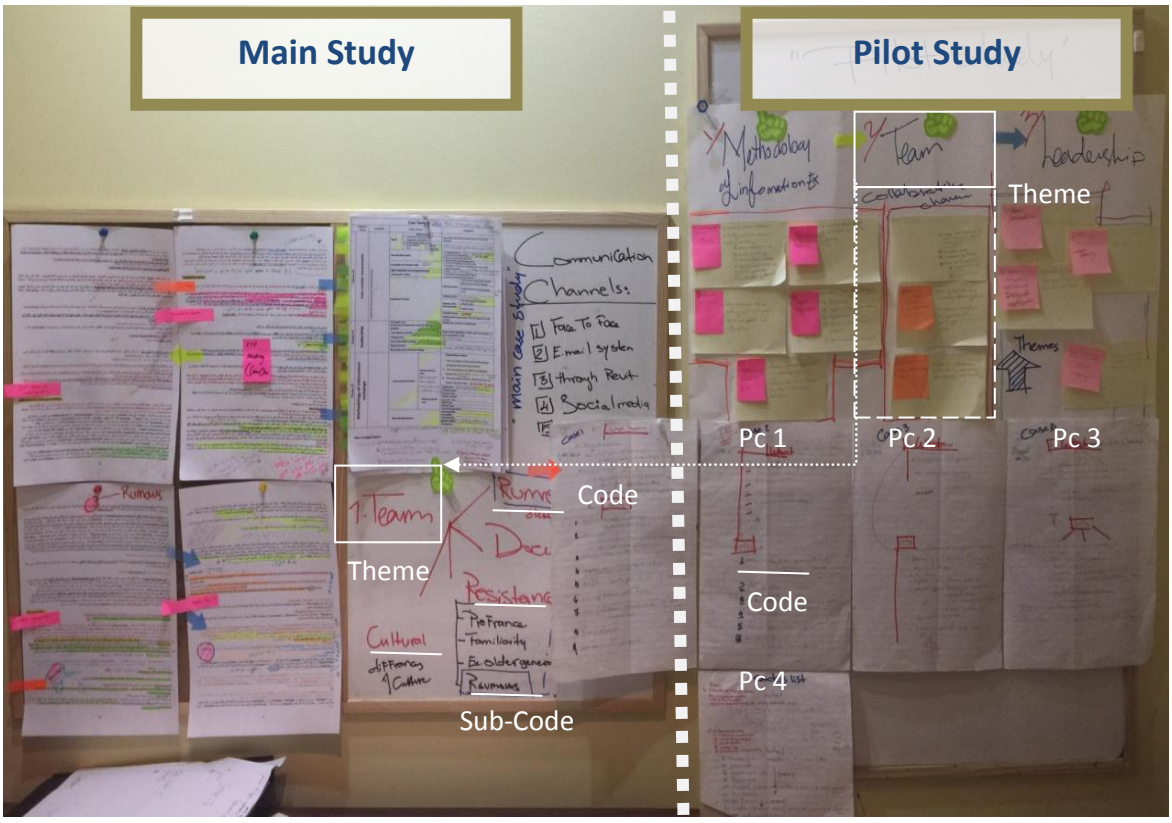

Figure 3-3: Snapshot showing the third step for the coding process

impact of rumours at the level of leader/ manager) under the main previously identified-code: impact of spread rumours. In this sense, this step contributed to splitting the main code, 'rumours,' into subcodes.

To illustrate this point, the pilot study recordings (i.e. the four audio interviews) were reviewed several times in different situations such as when performing

personal tasks (i.e. cooking, shopping, etc). In fact, the review of the responses in different settings afforded the researcher the opportunity to recognise and capture similar responses that were expressed by pilot study participants, particularly when they were asked about the impact of rumours on communication channels.

Following this process, their responses were checked against the written transcripts in order to support the researcher's understanding of the data. Here, it is important to note that a common statement that recurred in these transcripts that also appeared in the main case study data concerned the role of rumours:*"Our work environment is a professional environment."*

At this point, this recurring statement led the researcher to reflect on who made statements to this effect and their organisational roles in the pilot study. Interestingly, in the pilot study, the respondents were all managers. As a result, the researcher took a further step and reviewed the coded data for the rumour code, but this time for the main case study. According to this, it appeared from such reviewing process that, in the main case study, such previous repeated sentence has also been found which has been repeated by the manager and leader. This similarity in participants responses for managers and leaders in both the pilot and main case studies led the researcher to split the rumour code into sub-codes for three categories: 1) the manager/leader level; 2) the individual level; and 3) the top management level. It is worth noting that the preliminary findings of this pilot study were published as a conference paper (see Alnaser and Harty 2016).

- ***4th step***: The literature and relevant theory was reviewed along with the analytical framework discussed in Chapter 2. This analytical framework identified, defined, and discussed 38 potential influential factors according to their influence based on the literature and theory. This process afforded a comparison of findings in the literature and the empirical data set and allowed for interpretation of the interview data from different perspectives (i.e. theorists, scholars, and the research participants from both the pilot and the main study). In addition, it helped to identify additional codes to add to the second list. This step was key in refining the third coding scheme.

The analytical framework for this study is discussed in Chapter 2. The framework consists of predetermined codes, which Creswell (2009:187) termed a qualitative 'codebook,' which he described as *"a table or record that contains a list of*

predetermined codes that researchers use for coding the data. This codebook might be composed of the names of codes in one column, a definition of codes in another column, and then specific instance (line numbers) in which the code was found in the transcript." Although these predetermined codes are outlined in Chapter 2, for this research the coding analysis was a combination of predetermined and emergent codes.

- ***5th step:*** The emergent codes were listed, and all relevant research participant quotations were grouped under each code (see Figure 3-4). This step afforded the researcher yet another opportunity to understand and interpret the data and to understand the relationship between different codes (see Figure 3-4). For example, the relationships between the codes *rumours spread* and *lack of trust* and *rumours spread* and *resistance to change*, and their effect on changing communication channels. In addition, from a preparation standpoint, each participant's transcript was identified by colour, which further facilitated the coding and analysis process by tracking the occurrence of factors (i.e. codes) and their subsequent effects on communication channels (i.e. codes), if any. Importantly, this process facilitated the data analysis process and gave the analysis a narrative characteristic.

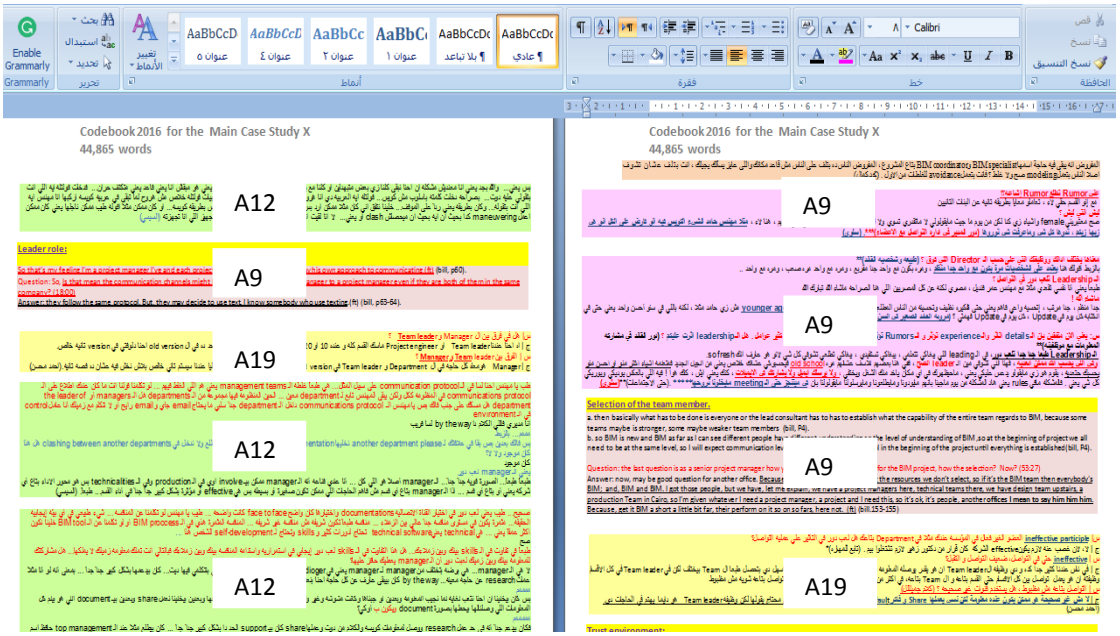

Figure 3-4: Screen shot of a Word file arranged by participant quotes and emergent codes

- ***6th step*:** The emergent code list was used to identify themes (see Figure 3-5). As Braun, V. and Clarke (2006:10), stated, *'A theme captures something important about the data*

in relation to the research question, and represents some level of patterned response or meaning within the data set.' From Creswell's (2009) standpoint, these themes are the ones that appear as *'major findings'* in qualitative studies and are often used to identify *'headings'* for the findings section.

For this study, three overarching themes emerged from the coded data: leadership, collaborative team characteristics, and methodology of the information exchange. These themes represented the repeated patterns of topics and meaning across the entire data set in relation to the research question (Braun, V. and Clarke 2006).

Along with qualitative audio data, the photographs were taken of the work's environment. These photographs, along with the background of the researcher as an interior architect to some extent contributed to understanding the participants' responses by analysing their statements while giving consideration to the role of workplace layout (e.g. there is s floor plan in 2D for x department, see Figure 5-7, Chapter 5). This process was paired with relevant images (see Figures 5-1 through 5-6) to clarify and support the researcher's interpretations.

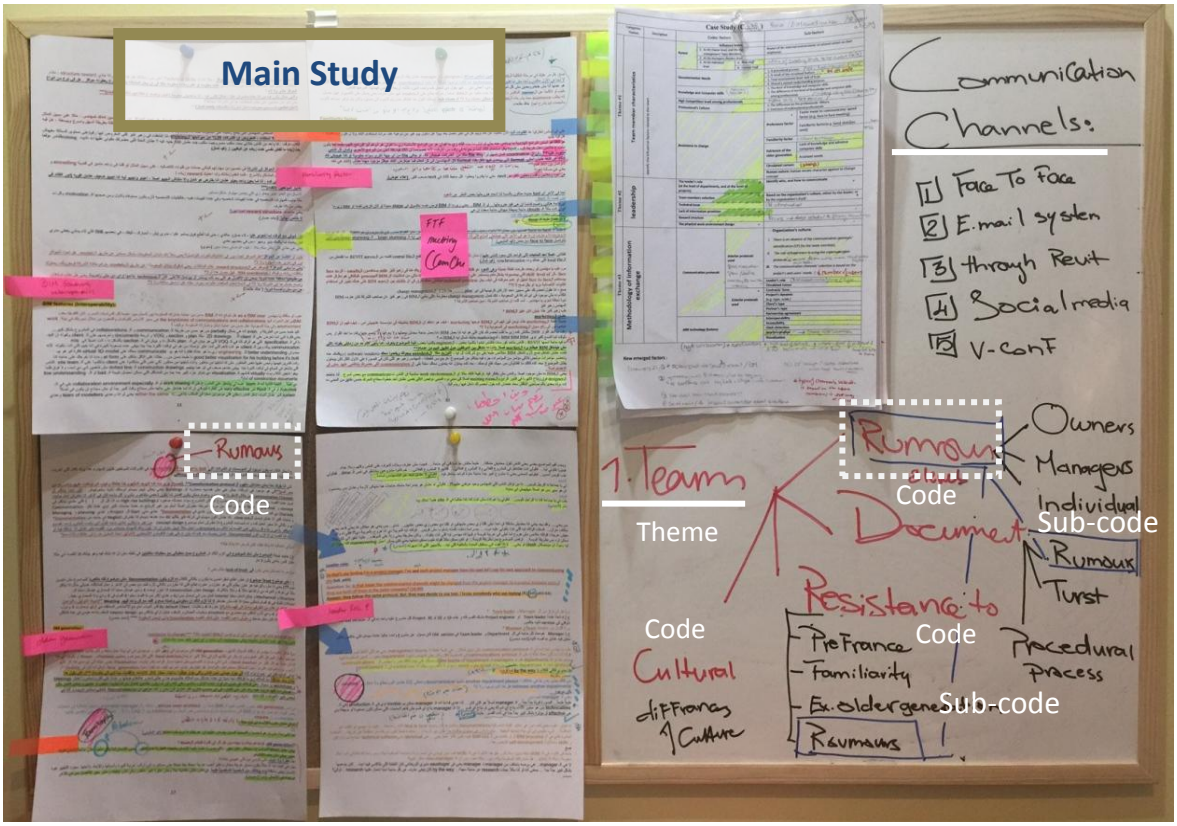

Figure 3-5: Snapshot for final theme generation phase

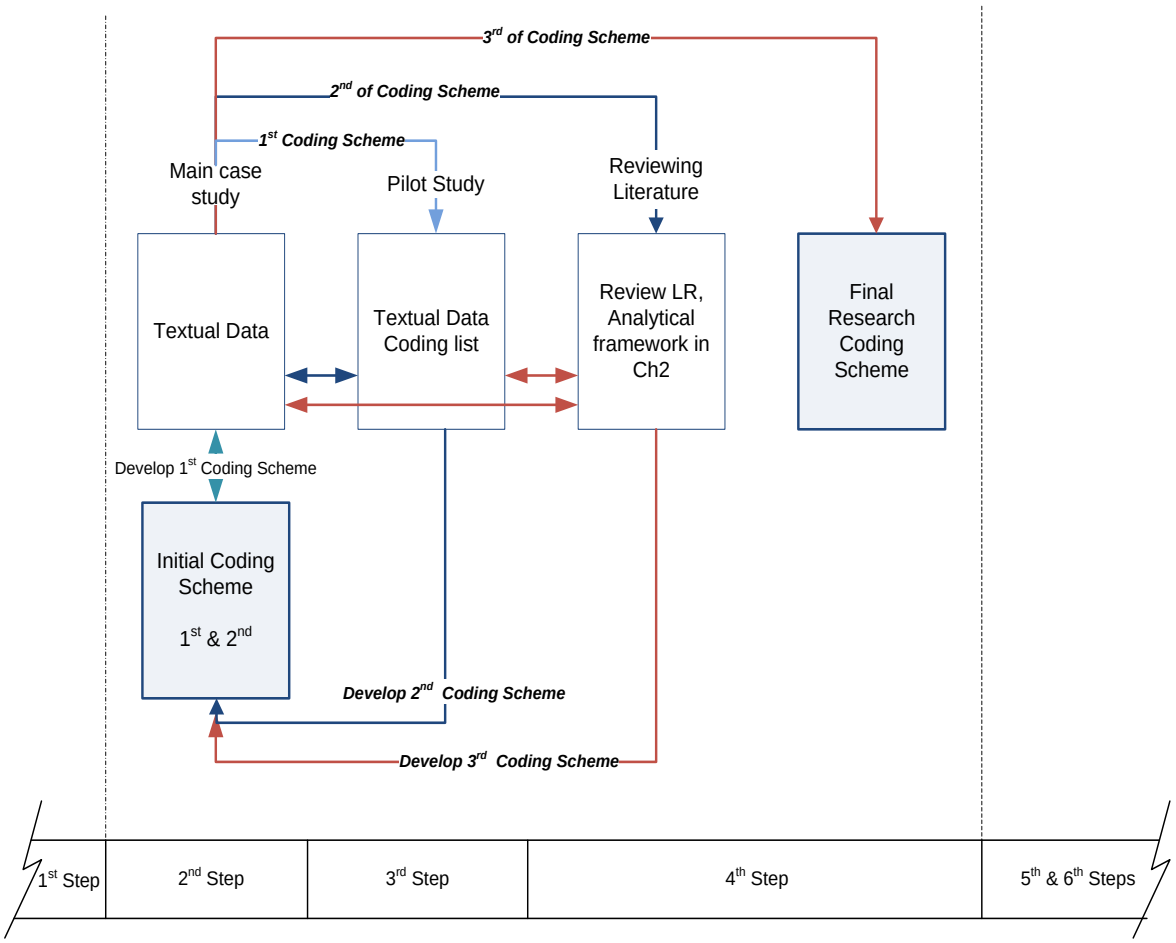

Figure 3-6: A summary of the process for developing the coding scheme

3.4 Research ethics and confidentially

All required ethics approvals were submitted and approved by the SCME school research committee before data were collected. In addition, all necessary materials, such as the information sheet, consent form and the interview protocols were designed based on the University of Reading's ethics approval protocol.

3.4.1 Informed consent

All participants were provided with an information sheet that explained the research study and its data collection techniques (see Appendix 4). The researcher also received permission from all involved organisations and forwarded this consent to the Saudi bureau to approve the data collection process.

All participants were also informed that their participation in this study was voluntary and that they had the right to withdraw anytime and to decline to answer questions. In this regard, in response to a request from one of the participants, the researcher removed the participant's response regarding a particular issue at his request. Moreover, the researcher secured permission from participants photograph their workplace, drawings, and meeting rooms. It is worth noting that although the organisation's department directors selected the research participants, a few requested to be excused from participation in the study.

3.4.2 Data management

The researcher followed the University of Reading's data protection regulations. First, the researcher informed participants that their information would be kept confidential and not seen by anyone other than the researchers and her supervisors. Second, the researcher agreed to destroy all data recordings, transcripts, and photographs after five years. Third, participant identities, job titles and organisation names have been kept confidential and were identified only through assigned reference numbers. Finally, all data, text and other information have been secured in a safe place.

3.4.3 Confidentiality

For both the pilot and main study, the research participants and the organisation names were kept confidential and referred to only by reference number. Furthermore, the raw research data has not been viewed by anyone except the researcher and her supervisors, and all interview text was transcribed and translated by the researcher.

3.5 Study limitations

This section presents the limitations of this study, including the challenges that the researcher faced during her data collection trip. First, because the case study is located far from the researcher's residence, additional costs were incurred for accommodation and transportation. Secondly, while the case study organisation provided the researcher with a place to work, it was located within its interior design department, where a majority of the staff were designers who use CAD, save for one architect (i.e. BIM user), who was interviewed. Third, during the data collection phase rumours were circulating within the firm about the possible closing of the branch and potential staff dismissals and relocations. As a

result, there was unforeseen tension in the branch. On a few occasions, one respondent asked the researcher to strike his interview comments about a particular issue, despite clarification regarding the confidentiality of this information.

In addition, the researcher encountered some difficulty meeting with professionals due to schedule constraints and temporary staff moves to another branch. This led to lost opportunities to interview some of them in person, and they had to be contacted via telephone. Finally, the research interviews were conducted Arabic, and thus took great effort to transcribe into English.

3.6 Summary

Chapter 3 outlined the research strategy and methods adopted for this research. Chapter 4 introduces the data analysis methods and discusses the preliminary findings of the pilot case study, Chapter 5 presents the results of the qualitative data analysis for the main study, and Chapter 6 discusses these results.

Chapter 4

The Preliminary Findings for the Pilot study

Chapter 4. The Preliminary Findings for the Pilot Study

4.1 Introduction

To expand on Chapter 3: Research Strategy and Methods, a pilot study was conducted as a preliminary step in addressing the purpose of the main study. This pilot study was used to refine the research questions, identify suitable cases, and test the data collection method. This chapter presents and discusses the preliminary findings of this pilot study[2].

The pilot study was designed to follow a sequential exploratory strategy (see Figure 4-1) and collected data using eight questionnaires and four interviews. There were two objectives to administering the questionnaires: 1) to identify the types of communication channels used in BIM environments; and 2) to measure the frequency of use of these channels. In addition, the quantitative data collected here helped in refining the interview questions by selecting for the most likely influential factors (Creswell 2009). In addition, a triangulation strategy was employed for each organisation, which allowed for testing of the interview questions (Bryman 2012) and improved the quality of the interviews.

It is worth noting that the interview questions were initially drawn from the literature and tested with two BIM professionals with more than four years of experience. The questions were refined using the questionnaire responses, which provided insight into the communication channels and influential factors that were discussed in the interviews. The four semi-structured interviews were conducted with an architect, a BIM coordinator, and project managers for four organisations. The data were collected from three mid-sized firms, and the last interview was conducted with a project manager from the Kingdom of Saudi Arabia's Ministry of Health (see Figure 4-1). The data collection process was conducted between June and August 2015 using email for the questionnaires and telephone interviews.

This chapter consists of three sections. The first section presents the thematic analysis, the second discusses the results, and the third summarizes the findings.

[2] It is important to note that this chapter is part of a conference paper published in the CIB World Building Congress 2016, Tampere, Finland; 2016. See (Alnaser and Harty 2016)

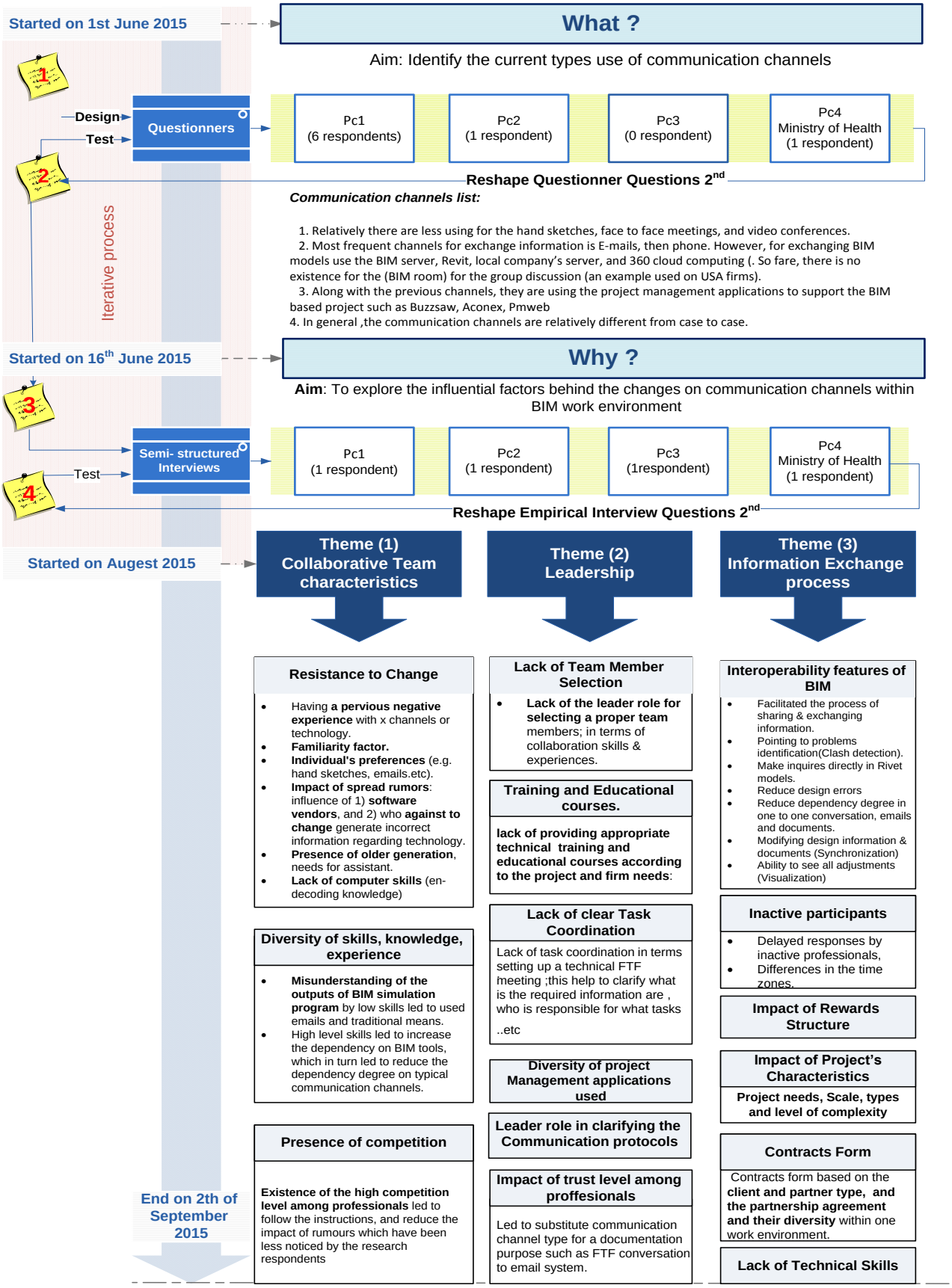

Figure 4-1: Summary of preliminary pilot study findings of communication channels used within BIM environments and if and why they changed over time. Three main themes emerged (at bottom), and an initial list of communication channel types appears at the top.

4.2 Organisation[3] profiles

The data for this pilot study were collected from four organisations considered to be leaders in BIM implementation in Saudi Arabia. Table 4-1 profiles these organizations.

Table 4-1: Profile of pilot study organisations

Organisation	Description
Pc1	Pc1 is one of the leading Saudi architectural, engineering, construction management firms with over 35 years of national and international experience. The firm has completed BIM-based projects ranging from domestic and international airports, hospitality facilities, medical care centers and large offices. Pc1 provides professional services ranging from architectural and engineering design, mechanical, electrical and plumbing (MEP) engineering, construction management, interior design, master planning, landscape architecture, and project management. The firm employs thousands of professionals and support staff at its head office and five branches (three in Saudi Arabia and two overseas).
Pc2	Pc2 is a design, engineering, and consulting firm that uses BIM throughout the life of its projects, which range from health care facilities, education centers and mixed-use developments. The firm employs experts in efficient, renewable and passive technologies that allow it to shape both building design and policy through its relationships with government and international clients and joint venture partners. Pc2's design teams use the most current technological and operational knowledge at its several branches.
Pc3	Pc3 is a full-service construction management firm that provides services from planning to commissioning. The firm currently manages various projects at multiple phases, including the King Khalid Medical City project in Dammam, Saudi Arabia, which will be one of the largest medical facilities in the world, and the largest expansion in history for the King Faisal Specialist Hospital and Research Centre.
Pc4	This project manager works with the Saudi Ministry of Health as government client liaison with Pc3 for projects such as the King Khalid Medical City and the King Faisal Specialist Hospital and Research Centre.

[3] The researcher obtained this information from the organisations' respective web sites.

4.3 Data analysis and preliminary findings

4.3.1 Theme 1: Collaborative team characteristics

Resistance to change: For this category, study respondents identified to several factors that influence communication channels. A recurring factor was a negative experience with specific communication approaches, software, or technologies. In addition, some respondents identified negative experiences with their colleagues at the individual or manager level. Based on these responses, those who 'resist change' have tended to disseminate incorrect information, such as difficulty levels and effectiveness for desired tasks. In addition, it was evident that software representatives play a role in convincing individuals and management to adopt certain BIM communication approaches. Furthermore, one BIM coordinator noted that, *'We are obliged to follow up with the senior management directives, particularly those that relate to the mechanism used for communication channels for information exchange'* (BIM Coordinator, Pc 1). However, it was not clear that any obvious change had been made in the communication channels used, particularly at the individual level. Along these lines, the project manager (PM) for the Riyadh medical centre project commented that, *'…one of the challenges we face is how to get our employees away from using the communication channels that are not listed in the planned communication model. In particular, for large projects, the use of email by some employees kept some essential information from the rest of the team, especially if such person has been changed [i.e. left project]'*" (PM, Pc 2).

However, a difference emerged between the use of specific communication channels (such as email) and technologies. The participants often seemed surprised when asked about the potential role spreading 'incorrect' rumours might play in changing or resisting the communication channels used. From their responses, the influence of such rumours appeared more in terms of technology use, rather than for communication channels. In light of this, such technologies can involve the use of a range of alternative channels, so the ultimate influence will lie within the use of those channels. Along with the effects of rumours, there was an indication that some changes and impacts are rooted in the influence of software vendors as *'…one of the influential factors most likely arising from members who resist to change and software vendors'* (BIM manager, Pc 3).

Individual preference was also important, with one respondent noting that, *'Individual preference plays a vital role in the communication channels used, and appears more obvious with respect to decision-makers'* (PM, Pc 2). However, another response indicated that the

individual preference often results in considerable challenges for project managers. Thus, individual preference led some professionals to continue to use hand sketching and email as their primary means to share information, which the PM stated was due to a *'familiarity issue'* (PM, Pc 2; PM, Pc 4).

The final sub-factor is the presence of older workers on project teams. From the BIM coordinator's perspective, *'…the older generation refuses to utilise new technologies because they believe such technologies will reduce their value and capabilities. I'm not surprised that this is what they believe'* (BIM Coordinator, Pc 1). Such resistance led other professionals to revert to using more traditional means of communication that are not included in communication protocols, such as face-to-face (FTF) meetings, hand sketching, email and paper documents. Furthermore, some respondents indicated the influence of a lack of computer skills. For example, the BIM coordinator stated that, *'…sometimes we assign an assistant to do all the technical things for him [the employee] due to his deficiency in how to manage technical issues and the encoding-decoding process.' This, in turn, '…led some [employees] to use alternative channels…. Thus, there were some changes in the type of communication channels used, and on the workflow process'* (BIM Coordinator, Pc 1).

Diversity of professional skills, knowledge, and experience: As the conversation with the BIM coordinator implied, an important factor is the influence of the diversity of skills, experiences, and knowledge among professionals. He indicated that:

> *'… the different skills and experience among the engineers was one of the reasons behind the misunderstanding of the outputs of the BIM simulation programme… especially in the technical and mechanical drawings stage.... In this case, some experienced professionals do not have any choice but to follow the lower-skilled professionals in design by using a 2D projections [i.e.CAD]. Certainly, in this case they used email as a channel for exchange rather than the BIM server.'* (BIM Coordinator, Pc 1).

In the other hand, some respondents stated that increasing the level of professional skill and experience also contributes to changes in communication channels. They depended more often on BIM tools, not only for exchanging data but also for sharing the work of other professionals. Thus, this contributes to *'reducing the degree of dependence on traditional communication channels for seeking information'* (BIM Coordinator, Pc 1).

Competition among professionals: Within BIM collaboration environments, when attempting to explore the impact of rumours on changes in channels, these rumours often appeared at the managerial level. However, at the individual level, this was less obvious. Moreover, respondents frequently mentioned the high level of competition among professionals. For example, the BIM manager stated, *'In my experience, I haven't seen it much because there are some challenges and a high level of competition. So, people just focus on being the best….then a negative actor might exist, but his influenced might not be noticed'* (BIM manager, Pc 3). This suggests motivation to change where the competition to perform can lead to individuals adopting new technologies and communication channels.

4.3.2 Theme 2: Leadership

Many responses suggested that team leaders and managers play an important role in making changes to existing communication channels. Many of these changes were explicit and appeared directly; others emerged indirectly. Some examples included team member selection (in terms of collaboration skills, experience, etc.), provision of training and educational courses, and lack of clear task coordination. And while classifying the influences on communication channels as either is direct or indirect is beyond the scope of this pilot study, some interrelated impacts emerged that resulted from these factors, such as individual differences in learning new technologies and resistance by older team members to change that restricted other team members to more traditional communication media (e.g. CAD files, email and paper documents). As one BIM coordinator stated, *'In any project, teams normally work at the same level of performance and experience, and selecting these teams is a core role of leader…. Another strong factor is project type; some projects are less difficult, and the choice of team members must be commensurate with their performance, background, experience, and skills'* (BIM Coordinator, Pc 1).

Another factor that affected the selection of communication channels was the lack of technical training and educational courses to match project and professional requirements. Still another concerned the lack of task coordination in terms of setting up technical FTF meetings, particularly at the outset of new projects. Typically, these procedures serve to clarify information requirements and assign tasks. However, the initial findings did not shown a direct influence of these factors on existing channels. There were expectations from many respondents, such as the project manager, who stated, *'…ambiguity around information concerning what and to whom [team members] have to send information…or sometimes,*

what the required information is, might lead to the need to document the communication process between the sender and receiver' (PM, Pc 4). However, when asked to provide examples, he stated that, *"…required information can [often] be sent by phone or through informal FTF conversation…but senders or recipients might be wary, that the other person might state that he didn't receive anything…. In this case, the actor might use some [communication] means that provides documentation, such as email*.' However, the initial findings also did not show a lack of task coordination as a direct influence on existing channels. On the other hand, this suggests that this factor can affect the level of trust between participants, which could lead them to use alternative channels, such as substituting emails for phone calls for documentation purposes. It is worth mentioning that all participants emphasised the role decision makers play in establishing communication protocols. Such protocols dictate required communication channels and project management applications to be used.

4.3.3 Theme 3: Information exchange processes

The respondents indicated that interoperability, which BIM technology provides, generally facilitated the process of sharing, exchanging and modifying information. However, in terms of BIM affecting communication channels, one BIM coordinator stated, *'The process became clear to all participants, which facilitated communication processes and information exchange…. Each person has the ability to see all adjustments, instead of talking with each person and explaining it individually…or sending a request for information via email'* (BIM Coordinator, Pc 1). Another PM stated that, *'…email has not generally been used as before for BIM-enabled projects'* (PM, Pc 2). In light of this, it appears that BIM has reduced not only the frequency and use of FTF meetings but also the use of email and hand sketches. In addition, other factors included delayed responses by less active participants and differences in time zones. For instance, inactive participants often resulted in shifting from exchanging BIM models using a BIM server to drafting and sending CAD documents via email.

The majority of respondents did not indicate a clear impact of incentive and reward structures on changing communication channels. However, one stated that these *'…might be influential, especially in some cases, such as when team members fulfil their duties correctly and on time.'* In exploring how this factor could influence channel use. The BIM coordinator stated, *'BIM has facilitated the process for sharing information around design details, but not shown of how they did these procedures.'* He also stated that, *'…if the work procedures have*

been done, or the technical issues have been sorted out, but in easier and faster way than what we planned to, normally the leader would ask him to share this knowledge with other team members, and this person would be rewarded for his efforts.' This statement suggests that a reward structure contributed to improving the process for sharing knowledge and addressing the lack of technical skills that respondents considered as influential on changes to channels used. In addition, these responses suggest the influence of both project characteristics (e.g. project requirements, scale, type, and level of complexity) and the form of partnership agreement used. In light of this, a lack of information provision with respect to the contractual agreement, in terms of clarifying the communication protocols such as the number of meetings, communication means (e.g. channels, project management applications) had made changes on communication channels according to both of the project managers for Case 4; and Case 2.

4.4 Discussion

To investigate factors that influence changes in communication channels, this pilot study analysed four case studies and collected data using four interviews and eight questionnaires. This analysis yielded several findings that relate to previous research in the communication, team, and collaboration literature. These empirical results revealed some influential factors, as shown in Figure 4-1. The case studies analysis supports the literature that suggests the presence of these influential factors, but in this study their effects were different. The findings revealed sets of relationships with respect to aspects of communication, teamwork, and collaboration, and subsequently their potential influences on communication channels used by design teams. While these results support the literature that suggests that individual preference, resistance to change, and organizational culture are important, it is worth noting that the factor termed 'spread of rumours' has not yet been addressed in the communication literature but appears to influence changes in communication channels. These findings show that this factor can play a critical role at the management level, and demonstrate the influential role software vendors often play in suggesting technologies and therefore communication channels. However, the influence of rumours was more difficult to discern at the individual level, perhaps due to the highly competitive interactions between professionals within BIM work environments.

In general, several factors influenced individual preference for privileging some communication channels over others. In particular, the factor of familiarity with certain

channels was one of the main drivers, despite employees having training and educational courses. Our findings are consistent with those of Watson-Manheim and Belanger (2002) in that both studies found consistency in terms of factors and in the interpretations behind impacts and changes. The familiarity factor emerged more clearly among older professionals who claimed to lack computer skills. Taken together, these factors constitute 'resistance to change'.

In addition, Within a BIM-based project, the relative absence of hand sketches as a 'familiar technique' was considered less acceptable for older generations. It was found that the need for using hand sketches as non-verbal communication paired with BIM tools is being used less than before (i.e. non-BIM cases). However, our findings suggest, in this respect, that the absence of such techniques might constitute a threat to older professionals' status and the level of their hand-drawing skills developed during their careers. Such skills may be the very reason why they arrived at such position in their companies. Alongside this, we might also consider the importance of hand sketches as a visual language as Sebastian (2011) stated, and a vital communication tool from the view of Homayouni et al. (2010) which is used to support clear communication during meetings. Although FTF meetings may be the most preferred means to communicate (Gabriel and Maher 2002), our findings are consistent with Dossick and Neff (2011) in terms of hand sketches being used less during meetings in BIM projects. Surprisingly, the skills, experiences, and knowledge as high or low for the team members, have contributed to making changes on communication channels used. To illustrate that, highly skilled professionals can shift faster between using the traditional channels (e.g. E-mails system, phone calls) to utilising BIM tools (e.g. BIM server, open request on Revit® building design software). In contrast, at the low-level skill, the need for face to face discussion remained along with emails for making inquiries. The main feature of BIM as an interoperable system, not only potentially produces a free error design, but also facilitates sharing what others have exchanged, pointing to problems identification and inquires directly in the Rivet models. These features not only reduce design errors but also, reduced the dependency degree on (one to one) meetings, emails, paper-based documents (e.g. hand sketches) and informal discussion. These findings seem to be agreed with the findings of Dossick and Neff (2011) in examining the changes occurring by using BIM.

Another factor that influences communication channels is documentation requirements and the need to record communication content to provide evidence for the exchange of official information among professionals. In particular, it has been found that the workplace is

sometimes characterised by a lack of task coordination among professionals. Furthermore, if a lack of trust exists, there is arguably a need to record communication processes, which is consistent with Watson-Manheim and Belanger's (2002) findings regarding influences on the selection of communication channels. However, this could also be attributed to ineffective leadership, as Ebrahim et al. (2009), and Amabile et al. (2001) indicated.

An additional influential factor that emerged was the communication protocol included in contractual project requirements and partnership agreements. The study findings are consistent with Emmitt and Gorse (2003), in that the determination of formal communication channels is associated with the contractual requirements of each project. As the results revealed, communication protocols differ by project type and scale, partner type, and the level of complexity. This diversity in protocols resulted in changes in communication channels for different contexts. These findings align with Dainty et al. (2006) in arguing that the need to expand communication across organisational boundaries is an inevitable consequence of increased project scale and can result in an expansion of the types of channels used. Furthermore, our findings indicate that the range of project management applications is normally based on project type and firm requirements, which can result in differences in communication channels, depending on context. However, questionnaire results did not allow us known about the percentage rate of used for each channel or whether this percentage rate for a particular channel is decreased, or increased after implementing BIM. However, overall the use of email, FTF meetings, video conferencing and phone calls are still employed within BIM environments, but the use rates are less than non-BIM projects.

In sum, this study explored the key question of the effect of BIM-enabled projects on communication channels and why this effect occurs by conducting case study research on the emerging role of BIM in a design team context. This study presented a list of factors that were evaluated using applicable theory and the communication, teamwork, and collaboration literature. These factors were categorised according to their influence in these bodies of literature, which in turn facilitated the data analysis process. As a new approach that has not yet been addressed in the literature, this study identified 38 factors that can be used as a guide to determine potential changes on communication channels in design team contexts. Identifying these factors was a fundamental step in identifying changes in communication channels due to the adoption of any new technology.

Based on the pilot study results and the literature, some commonalities in influential factors emerged across various research fields. However, as these findings are seen as an initial

attempt, more extensive research needs to be conducted to further understand the implications of BIM for communication channels. This study concludes that the initial approach of solely relying on communication theories is not sufficient for understanding and interpreting communication changes in a BIM-enabled context. Therefore, the employing of the three communication theories, although there are relatively diverse, including team and collaboration theories, have provided another dimension and insights to this study.

Finally, a few limitations of this pilot study should be noted. First, the much of data relies on a relatively small quantity of participant feedback. Second, no substantive quantitative data exists to support the study conclusions. These limitations were considered as further research was undertaken.

4.5 Summary

This chapter discussed the preliminary pilot study findings of semi-structured interview and questionnaire data for respondents at four mid-sized Saudi firms. The data analysis revealed three main themes: collaborative team characteristics, leadership and methodology of information exchange. In addition, the initial results showed that resistance by professionals to changing to new or alternative communication channels related not only to lack of training and education but also to a 'familiarity' factor. Furthermore, the findings showed an effect of 'spreading rumours' (i.e. pre-existing assumptions and expectations) on adoption of communication channels, which most commonly appeared at the decision-maker level. Based on the pilot study outcomes, Pc1 was selected to be the main case study for this dissertation. Chapter 5 presents the thematic data analysis for the primary study.

Chapter 5

Case Study Thematic Analysis

- *''Overall, when communication channels touch the senses [are tangible], communication process are more effective. If you can see, hear, and hold… you feel it. I mean, the ability to deliver information is better."*

- *"The effectiveness of communication channels is classified by the senses [e.g. aural, oral, visual], …. And the least effective [communication channel] is reading [i.e. emails]….''*

A1, Design Manager

Chapter 5. Thematic analysis

5.1 Introduction

This chapter discusses the research results of the main case study (Mc1) data analysis. These data were transcribed, coded, and classified into three themes: 1) team member characteristics; 2) leadership; and 3) methodology for exchanging and sharing Information (see Table 5-1). This section presents these themes and the influential factors that drove changes in the mechanism used to select communication channels in Mc1's BIM environments. In addition, it addresses the research question of "What happened with communication channels, and why?" To address this 'why' question, Table 5-1 lists the influential factors that drove these changes and summarises the structure of the data analysis. Table 5-2 presents a list of communication channels that are currently used in the BIM environment. This chapter also presents participants' responses in terms of how these derived factors influenced these communication channels (see Section 5.3).

Throughout this chapter, underlined statements in the text delineate these changes in communication channels, their nature, and why they occurred. Put another way, these statements identify the influential factors that emerged in this study. In addition, brackets to the left of the respective respondents' statements list additional pertinent information (e.g. body gestures). Moreover, images have been included to assist in illustrating the design of the case study workplace and the communication channels and tools used by BIM users in that workplace.

Table 5-1: Summary of the study themes and emergent influential factors

	Case study (Mc1)				
	Categories (Themes)	**Codes (factors)**		**Codes (Sub-factors)**	
Theme #1	**Team member characteristics**	**Rumour Spread**		**Influence levels**	
				Owner and top management level	
				Manager / Leader level	
				Individual level	*New staff*
					Existing Staff
		Documentation needs		***Procedural processes***	
				Consequence of rumours	
				Trust environment level (.e. lack of trust)	
				Shared mutual understanding/purpose	
		Knowledge and computer skills		***Level of knowledge and computer skills***	
				Difference in the level of knowledge and computer skills among professionals	
		Competition level among professionals			
		Professional culture		***Difference in the professional culture***	
				Existence of multinational professionals	
		Resistance to change		***Preference factor***	*Faster means to communicate/speed factor (e.g. in-person meetings)*
					Familiarity factor (e.g. hand sketches used)
				Familiarity factor	
				The existence of the older workers	*Lack of knowledge and advanced computer skills*
					Assistant needs
				Circulated rumours	
				Human nature *(i.e. innate resistance to change)*	
Theme #2	**Leadership**	**Leadership role**		**Identify staff and communication method**	
		Team member selection		**Based on organisational culture**, established either by the leadership or the organisation itself	
		Technical issues			
		Lack of information provision			
		Reward structure			
		Design of physical work environment			
Theme #3	**Methodology of information exchange**	***Communication protocols***	***Interior protocols used***	***Organisational culture*** – *Absence of communication protocols (CP) for team members* – *Role of experience in using communication protocols* – *Communication channel selection based on project and user needs*	
				Leadership role	
				Circulated rumours	
			Exterior protocols used	***Contract forms***	
				Project dynamics *(e.g. type, scale)*	
				Client type	
				Partner type	
				Partnership agreement	
		BIM technology features		***Interoperability***	
				Accessibility	
				Clash detection	
				Synchronization	
				Visualization	

5.2 Main case study profile and description

The selected case study (Mc1) is considered one of the leading and most established architectural, engineering and construction management (AEC) firms in Saudi Arabia with over 35 years of professional experience in both the domestic and international markets. This firm has successfully completed BIM-based projects ranging from local and international airports to hospitality projects, medical care centers and large-scale offices.

This firm provides professional services ranging from architectural and engineering design, mechanical, electrical and Plumbing (MEP) engineering, construction management, interior design, master planning, landscape architecture and project management, and employs thousands of professionals and support staff. The company has one head office and five branches: three in Saudi Arabia and two overseas.

Regarding Mc1's design process, the case study respondents identified five main stages: 1) concept design; 2) architectural concept design; 3) schematic design; 4) detail drafting and construction documentation; 5) design development and pre-final design. According to respondent A4 (the quality control director),*" Up to now, 30% of our design work has been done in the Saudi branches, with the remaining 70% at the international branches.''* Moreover, *"the firm calls this 70% the production stage."* The rationale behind shifting 70% of the firm's work to its international branches is twofold. Again, according to respondent A4, *"First, the majority of our work is requested to be in CAD, and second, the firm looks to use lower-salaried employees."*

Mc1 began to use BIM in 2010, and by 2012 they '*had completely shifted to BIM processes.'* (A15, Senior Project Manager). The firm consists of several departments, including interior design, design, sustainability, quality control and technical divisions. It is important to note that Mc1's main client is the Saudi government and that, *"…so far, the majority of our government clients, have requested our drawings in CAD."(*A15)**.** In addition, the firm has recently shifted its Saudi production to its overseas branches. It is important to note that one of these branches recently closed due to *''administrative issues related to the salaries, high staff turnover levels and the high cost of living… the percentage of staff turnover over the last three years was 35%, and the remaining staff who have worked since the office opened in 2008 is 10…."* (Senior Project Manager)

The analysis results revealed the current types of communication channels used among BIM users in the firm's communication processes (see Table 5-2). It is worth mentioning that these channels and their rates of use differ across contexts, and sometimes within one context (i.e. a department), which is largely due to the influential factors addressed in Subsection 5-3 and depicted in Table 5-1.

Table 5-2: List of communication channels used within BIM work environments

Communication Channels used within Mc1 BIM work environments		
Face-to-face meetings		One on one meetings
		Group meetings
Phone calls		
Video conferences		
Hand sketching		
Paper-based documents		
E-mail		Outlook
Social media networks		WhatsApp
		Snapchat
Link software		Instant chat
Team viewer		Used with CAD systems
Server	Local server	Used among professionals within one branch
	Revit server	Used among interdisciplinary design teams from different branches
	BIM server	Used among multidisciplinary design teams from different firms
Cloud system		Autodesk® BIM 360™
Skype business		
Project management application		e.g. ACONEX, PMWeb

5.3 Theme 1: Team member characteristics

This section illustrates some of the relevant factors associated with changes in communication channel use from a project team perspective. These factors have contributed to these changes either directly or indirectly. However, as discussed previously, this study did not focus on the type of influence (i.e. direct or indirect), but rather on the field of influence (i.e. changes in communication channels). It is worth mentioning that this approach applies to the entire study. In light of this, this section discusses a number of emergent Influential factors, which are listed in Table 5-3.

Table 5-3: Theme 1: Team member characteristics

Themes		Codes (Factors)	Codes (Sub-factors)	
Theme #1	Team member Characteristics	**Rumours Spread**	**Influence levels**	
			1. Owner and senior management level	
			2. Manager/supervisor level	
			3. Individual level	*a. New staff*
				b. Existing Staff
		Documentation needs	1. Procedural processes	
			2. A result of rumours	
			3. Trust environment level/lack of trust	
			4 Shared a mutual understanding	
		Knowledge and computer skills	1. The level of knowledge and computer skills 2. The difference of the level of knowledge and computer skills	
		Competition level among professionals		
		Professional culture	1. The Difference between the professionals' culture. 2. The existence of multinational professionals	
		Resistance to change	**1. Preference factor**	Faster means to communicate(e.g. face-to-face meetings)
				Familiarity factor (e.g. hand sketching)
			2. Familiarity factor	
			3. Older employees	Lack of knowledge and advanced computer skills
				Assistant needs
			4. Circulated Rumours	
			5. The innate human tendency to resist change	

5.3.1 Rumours spread

The influence of rumours spread was one of the key findings of the pilot case study, and based on its effect on communication channels, all research participants at the main case study were asked about its importance. It is worth noting that during the interview period, many rumours were circulating within Mc1's work environment. These rumours primarily concerned staff transfers to a different branch and its effect on team member stability in terms of turnover and dismissal. However, when asked to what extent these rumours might influence the communication channels used, the answers were varied. It is worth noting that this question often surprised the interviewees, and many of them answered it along the lines of this response:

- *"…rumour spread? Which rumours?… Ha, ha, ha."*

Thus, it sometimes seemed that respondents were reluctant to discuss these rumours, and on some occasions to explain what they (i.e. rumours) meant in a BIM work context. And although 'rumour' was a key term that had been frequently mentioned during informal

settings with the research respondents (e.g. lunch time and tea time), a few respondents refused to officially comment on this topic.

In addition, some respondents asked the researcher to amend the question regarding rumours. One remarked:

- *"You don't have a question other than the one about rumours? I don't understand this question.''* (He then turned his face and looked around in an attempt to move on to the next question)(A1, Design Manager, Mc1)

Some participants also asked the researcher to provide examples to clarify what she meant by 'rumours' and how they might influence the communication channels used, both in general and specific to BIM environments. However, two different findings[4] were presented to the research participants, whose answers and comments were diverse and were classified into three categories (i.e. levels): a) owner and top (senior) management level; b) manager/leader level; and c) individual level (see Table 5-4).

Table 5-4: The rumour factor

<table>
<tr><th colspan="2">Theme</th><th>Factor</th><th colspan="2">Category</th><th>Sub-factor</th></tr>
<tr><td rowspan="5">Theme #1</td><td rowspan="5">Team member characteristics</td><td rowspan="5">Rumours Spread</td><td colspan="2">1. Owner and top management level</td><td>Impact of the external environment</td></tr>
<tr><td colspan="2">2. Manager/leader level</td><td rowspan="4"></td></tr>
<tr><td rowspan="3">3. Individual level</td><td>Sub-Categories</td></tr>
<tr><td>C.1 New staff at the organisation</td></tr>
<tr><td>C.2 Existing staff at the organisation</td></tr>
</table>

5.3.1.1 Owner and top management level

Two respondents from senior management were interviewed, one of whom is the firm's general manager. Initially, both did not wish to discuss the existence of any workplace rumours, particularly among team members. However, the general manager pointed out the impact of one rumour on staff, noting that:

[4] It is important to mention that two examples of the impact of rumours used in the main study resulted from the findings of the pilot case study. These examples are: a) at the decision-maker level, software vendors often played an influential role; and b) at the individual level, no clear influence of rumours emerged, perhaps due to the existence of the high levels of competition.

- *''The rumour affected us dramatically, and its influence was twofold: First, with the employees, for example… I heard on TV that [external factors can affect peoples' jobs]... I received calls from several people, and they told me that they heard about this… The calls were at night and on the weekend... even on the weekend they spoke to me.''* (A2, General Manager, Mc1)

He continued:

- *'' Immediately, I spoke to an official that works in the Ministry of (X)… yes, it was at night… to check the truth of this unconfirmed information"* (A2, General Manager, Mc1)

Another statement suggested that the impact of rumours at Mc1 is not limited to the employee level, but rather another impact exists at the senior management level:

- *"The most important aspect that some owners tell us, for example, is we heard that [important projects] can stop as a result of the current economic crisis…. Yes, even at the owner level, rumours have an effect, and vice versa…. As long as there are parties who hear everything, there is no doubt that the influence of rumours is unreasonable."* (A2, General Manager, Mc1)

Taken together, whatever the influence of rumours may be on communication channels at the firm, these statements suggest that any potential impacts are not limited to the employee level. However, while the general manager denied any existence of workplace rumours, his statements suggested that the impact of the external environment on their team members and the clients as well subsequently led them to using informal channels as alternative means of having these circulated rumours either confirmed or denied.

These responses encouraged the researcher to request clarification to understand how rumours might influence top management in selecting communication channels. His answer differed slightly than his previous response:

- *''The selection of channels? No, this exists at the staff level. However, for top management, rumours are at a different level.''* (A2, General Manager, Mc1)

When asked to provide examples, he noted that:

- *"Sometimes, an employee comes up to me and says, could you please excuse me from communicating with (X) person? When I ask why, he tells me that he heard*

that this person spread rumours about him. To be honest, part of our time is lost in debates about unconfirmed information and things that do not exist at all.'' (A2, General Manager, Mc1).

The above responses led the researcher to ask if rumours play any role at the BIM execution stage. His answer:

- *"Yes, we have confronted some staff issues…. .Indeed, there was an attempt to disrupt or stop the adoption of BIM in our organisation.''* (A2, General Manager, Mc1)

This led the researcher to further enquire: During the BIM implementation phase, what rumours were circulating? He replied:

- *''The most widely circulated rumours were those I heard from the staff. They believed that using BIM would significantly reduce employment, because it would improve productivity and thus will increase the number of projects. Interestingly, these rumours were behind the resistance of some to adopting the BIM processes''* (A2, General Manager, Mc1)**.**

The respondent mentioned another rumour with respect to BIM processes:

- *''… that after the organisation adopts BIM, it will dismiss most of the staff, and only 10% to 15% of current employees will be needed to staffing all BIM-based projects.'"*

He noted that this rumour led some to *"…resist adoption of BIM for a while"* (A2, General Manager, Mc1)**.**

In sum, this discussion suggests that the influence of rumour exists at the top management level despite the reluctance of some respondents to discuss it. In addition, the rumours that are spread outside of the organization, particularly by television, have affected communication channels by prompting team members to communicate with upper management instead of their direct manager (e.g. telephone calls in the middle of the night to check the veracity of a rumour). Thus, the changes in communication are twofold: not only have the channels become more informal, but also the timing of communication has changed (i.e. outside office hours). Furthermore, such rumours have contributed to resistance to adopting a new technology (i.e. BIM).

5.3.1.2 Manager/leader level

The results showed that rumours also influence managers and the leaders, including Mc1's department heads, who maintained that rumours do not circulate at the firm. Some respondents stated that this is because their workplace is ''a professional environment." In addition, the following statements suggested that in general, managers did not wish to discuss rumours:

- *"No, I don't know, I'm not sure about our department…. I'm not the right person to answer this question. What is the next question?*" (A1, Design Manager, Mc1)

Similarly, another respondent commented:

- *"…our work environment is a professional one. There is no place for rumours….''* (A3, technical director, Mc1)

However, another manager described a recent incident with respect to rumours when the researcher asked if he had heard of any recent rumours within the organisation, especially with the new global economic crisis. It is worth mentioning that such a question was based on the researcher's knowledge of Mc1's work environment. For this reason, the answer takes on an additional dimension, especially considering that the respondents (i.e. managers and leaders) knew that the researcher was aware of the current situation due to time spent with their employees (i.e. approximately one month before the interview phase). As a result, to some extent, their answers are slightly different that those of the previous group, and perhaps more candid:

- *"…oh, yeah, something recently. I received a phone call from our colleagues at [X] branch, enquiring about a certain incident that occurred at our main branch in [X city]."* (A4, Quality Control Manager, Mc1)

When he was asked what the incident was about, he declined to answer, but did state:

- *''I didn't know about this incident, which occurred in my branch. I only heard about it from colleagues who were located remotely at [overseas branch name].''* (A4, Quality Control Manager, Mc1)

These statements suggest that the presence of rumours at Mc1 is not confined to a single workplace (i.e. branch), and the reaction to some of these rumours led to inquiries about the validity of the information. Therefore, the circulation of rumours have, as a whole, affected

the firm's communication patterns, both formal and informal, and subsequently the types of communication channels used. For example, increased demand for communication resulted in increased informal communication as opposed to communication through official channels in order to verify or discuss these rumours.

5.3.1.3 Individual level

As previously discussed, the case study interviews were also conducted with various team members at Mc1 ranging from designers, engineers, architects, and department heads. In contrast to the more senior managers, most of these professionals held similar views on the influential role that rumours can play the employee level. In addition, despite the significant influence of rumours, it appeared that this effect varied in terms of if they were new or existing staff (i.e. longer-term staff). In general, for both of these categories, the influence of rumours on communication channels was clear as the following statements demonstrate.

5.3.1.3.1 New staff members

- Part one: *''After I started work and explored the environment, colleagues asked me about what project I'll be involved in…I said it doesn't matter…. They told me to avoid (X) person…."*
- Part two: *"…based on what I hear, I have started to be very official with him, and if things don't require formal communication—for instance, email—I try to avoid direct interaction. As a result, I communicate through his secretary, for example.''* (A5, BIM Manager, moved recently from Mc1)

And another respondent stated:

- Part one*: ''…from day one, new staff members begin hearing from others about the organisation's positions, staff attitudes, recent conflicts, etc."*
- Part two*: ''…this is very common, not only in our organisation, but everywhere. Eventually, the work environment becomes a social environment. ''* (A6, BIM coordinator, moved recently from Mc1)

Here, the sub-question for this factor (i.e. rumour) was, *"How do rumours affect the communication channels used?*''. This respondent answered:

- *'' I found myself dealing either with (X) person or with the incidents, based on the background I acquired from my colleagues… honestly, just based on what they told me.''* (A6, BIM coordinator, moved recently from Mc1)

The underlined statements show the causes and effects of what employees heard (i.e. unverified information), and how this information affected their selection of communication channels. These statements show another aspect of the influence of circulated rumour in the way it affects not only existing staff but new staff also.

5.3.1.3.2 Existing Staff

One important issue here is the one respondent, a BIM coordinator, recently left Mc1. However, his statement below suggests that he has since been updated about events that have recently occurred at his previous workplace.

- *''Occasionally, some rumours circulate about managerial decisions, which leads people to become unfocused. Thus, they tend to involuntarily speak with others. Therefore, the optimal use of technology decreases, and we return to the human interface.''* (A6, BIM coordinator, [recently left Mc1])

This statement suggests that rumours about administrative matters played a role in making changes in the firm's communication channels in a direct and informal way. As an example of this impact, this type of rumour reflects the spontaneous nature of conversation for office professionals. As a result, this example shows the strong relationship between spontaneous professionals' conversation and rumours on changes in the communication channels used.

Similarly, another respondent commented on the spread of rumours:

- *''Normally, rumours revolve around decisions. For instance, changes in management or changes in(X) person's position."* (A7, Senior Architect, Mc1)

This led to the following sub-question: Did this rumour play a role in changing the type of communication channels used or affect the level of use of existing communication channels? He replied that, *''…definitely, at the level of use… the use of communication channels increased."* (A7, Senior Architect, Mc1)

Another example of rumour circulation among staff was:

- *''The most common rumours I hear at work are about the performance of (X) employee and (X) department…."* (A8, Architect, Mc1).

And another respondent A6 (BIM coordinator) commented:

- *''In the market, BIM is one of the most frequently mentioned terms among engineers, along with Revit and Revit courses. As a result, this leads people to inquire about what BIM is."*
- *''Consequently, engineers have started to learn Revit, and I'm one of them."*
- *"The professionals began talking with each other about Revit and BIM. The subject is being known, seating with you and start talking about the benefits, challenges of BIM.....all the debates is revolved around BIM [Revit]!!"*

In response to the inquiry about the nature of the rumours that circulated during the BIM implementation phase, the previous respondent noted that:

- *''Honestly, I'm one of those people who, when talking with colleagues, literally says, Anyone who won't work with BIM will be out of the market soon.''* (A6, BIM coordinator)

In addition, when asked about the philosophy behind implementing BIM at Mc1, the respondent mentioned the role of software vendors:

- *'' … software vendors came and spoke about BIM. Then, suddenly I found that all of the seminars were about BIM."* (A6, BIM coordinator)

With regards to the influence of spreading rumours whether is correct, or not, and how could it related to the communication channels changes. Also, Whether the rumour is about the work environment, or about (x) a person, the respondents referred to another factor which is the documentation needs. This factor is explained in the following section.

5.3.2 Documentation needs

Documentation is an important procedural process for any organisation. In fact, when discussing the issue of workplace rumours, the respondents often referred to the need for documentation. This section focuses on documentation and its relationship to: a) the

circulation of rumours; b) lack of trust; and c) shared mutual understanding, as well as how documentation may contribute to changes in the communication channels used.

Table 5-5: Documentation needs

Theme		Factor	Sub-factor
Theme #1	Team member characteristics	**Documentation needs**	Procedural processes
			Affect of rumours
			Trust level/lack of trust
			Shared mutual understanding and purpose

5.3.2.1 Procedural processes

Some respondents referred to the need for documentation processes and considered them to be official procedures. The underlined statements in this section refer to Mc1's current documentation protocols. For example, the director of the architecture department has structured his department's documentation process as a set of steps:

a) First, direct communication through one-on-one or group meetings;
b) Then, oral agreements on a solution;
c) Finally, generate documentation about what has been agreed to using official communication channels (e.g. email).

In other words, as the director of the architecture department stated:

- *''First, we communicate via face to face, then we solve the problem, then we document it using email, hard copy, soft copy, etc., saying this is what we agreed on. Then we list the solution."* (A3, Architectural Department Director, Mc1)

5.3.2.2 Affect of rumours

Similarly, another respondent supported the responses listed in the previous section (see Section 5.3.1), namely that one justification for documentation of communication via email was to have evidence which could either dispel or support rumours, if necessary, surrounding (X) person in (X) department:

- *''According to what has been said about (X) person, it is a pity to say, but I communicate with him in a formal way, when I have to…. A phone call, or a walk*

through to his office, is often enough. But I want to be in safe… and preserve my rights, as well.'' (A9, Design Architect, Mc1)

Here, it is worth noting the shift in the use of an informal channel (e.g. the telephone, FTF conversation) to a formal one (i.e. email), despite the fact that this was unnecessary. It is clear from A9's comments that the need to feel "safe" and to have documentation is important enough for A9 to change their channel of communication. As was previously discussed, two rationales for documentation at Mc1 are the need for office procedures and the presence of workplace rumours. However, the findings also show two additional justifications for documentation; they are introduced in the following section.

5.3.2.3 Workplace trust levels

The following interviewee statements demonstrate the connection between documentation needs within and across Mc1's various departments and the level of workplace trust:

- *'' …there is nothing called 'documentation' within one department, or communication between the design team members at one department… teams must act as one person. Documentation usually occurs across different departments, otherwise, something is definitely wrong."* (A11, Design Architect, Mc1)
- *''A lack of trust most often exists between one department and other departments, or disciplines, but definitely not within one department.''* (A10, Design Architect, Mc1)
- *''At the level of a single department, there is no need for email or other documentation systems. Everything is verbal, one-to-one, and group meetings.''* (A11, Design Architect, Mc1).
- *"…documentation is normally done through the organisation's email system."* (A11, Design Architect, Mc1)
- *'' …the choice of communication methods is based on the level of trust between employees and their partners, etc."* (A5, BIM Manager, recently left Mc1)

Some of these statements speak directly to workplace trust levels and how they have influenced communication channel use. This suggests that the use of communication

channels varies based on the level of trust among employees, and that some staff use formal communication channels in case they need to communicate with those in other workplace environments (i.e. different departments within the organisation). However, some suggested that the use of formal channels may indicate the presence of something untoward. In sum, while this study classifies this influential factor (i.e. trust level) as a sub-factor under documentation needs, it might play a major role as well in influencing changes in communication channels across contexts, and could be considered a main factor.

In addition, some staff referred to the need for documentation not only for the aforementioned reasons, but also as a metric of mutual understanding with respect to design information among related professionals.

5.3.2.4 Mutual understanding

The last subfactor in the documentation needs category is a mutual understanding among professionals. As the following statement suggests, this is another facet of the need for documentation (see Table 5-4). One respondent indicated that:

- *"Everything has to be documented. The issue is not related to trust; I want to ensure that project-related information has been received and understood correctly."* (A12, Sustainability Department Manager, Mc1)

In sum, these statements suggest that at least four factors are associated with the need for proper workplace documentation, both within and across departments. The study results show that these factors contributed to a shift from formal to informal communication channel use among design professionals at Mc1.

5.3.3 Knowledge and computer skills

Clearly, computer skills and knowledge play a significant role in technology use for any organisation. The remaining question for Mc1's BIM users was, What are the consequences of this fact on the communication channels used within BIM environments? Several responses are presented below.

According to one respondent A6, (BIM Coordinator, recently left Mc1):

- *"The email system, which is used by the technical team, who, in particular, work on the models, shouldn't be used anymore. But, unfortunately, it reflects the lack of skills of BIM users, and is not at all related at all any one type of the technology or software. The issue is the BIM users.''*

- *"… email use in the (X) office [another branch overseas] does not exist. I have visited this branch, and saw how they worked, and there was not a thing called email use."*

It was also relevant to ask about the correlation between employee skill levels and the need for communication. One respondent replied:

- *"… definitely, if the level of skill increases, the need for communication among employees decreases…''* (A1, Design Manager, Mc1)

In addition, it is important to note that another influence on communication methods is the difference in skill levels among employees in terms of encoding and decoding communication. As one respondent stated:

- *"……Of course, differences add value to the work. The differences in the team and their capabilities in using BIM has improved communication in one aspect and reduced it in another. As with any new technology, it has improved communication, and our higher-skilled employees tend to use it in a new way."* (A7, Senior Architect, Mc1)

One effect of these differences is that highly-skilled professionals tend to use more traditional means of communication to communicate with those professionals who have low skills. One respondent stated:

- *''For instance, colleagues occasionally have come to me and said that they haven't understood (X) problem or issue, or how to fix it. It is extremely difficult to find a team in which all members are at the same level of skills and abilities."* (A10, Design Architect, Mc1)

In sum, the influence of skills and knowledge levels affected the use of communication channels at Mc1, as did the difference in skills and knowledge among professionals as well. Nevertheless, for both cases, the more highly skilled professionals used the traditional channels which were compatible with the lower skilled professionals.

5.3.4 Level of competition among professionals

The results of the pilot study showed a high correlation between competition and skill levels among professionals. This lead the researcher to ask about the effect high-level workplace competition could have on them improving their skills, and furthermore, any resultant effect on communication channels.

It is important to note here that one finding of the pilot study was that in contrast to the decision-maker level, there was no effect of rumours on changes in communication channel use at the employee level. Based on the pilot study results, this was due to the high level of competition that exists among pilot study's employees. For this reason, a similar question was posed to the main case study participants.

One responded that:

- *''We should constantly update our skills to match the Autodesk updates…. Oh, and competition exists among our employees, particularly among the newer generation, to improve their skill levels.''* (A13, Structural engineer, Mc1)

This statement led to a further inquiry about how this could potentially influence communication channels. He continued:

- *''Thus, this resulted in improved abilities in decoding and encoding design representations. Certainly, it reduced our need for communication and inquiries for unclear or incomplete information… which is normally a result of a lack of technology use.''* (A13, Structural engineer, Mc1)

Again, it is important note that before BIM was implemented at Mc1, none of the team members had any knowledge of BIM. Consequently, in terms of BIM skills, all of them began at the same level. Since 2009, Mc1 has trained its employees in BIM use, which has improved their skills. To date, they have now reached *"…the same skill level. So, the learning curve is constant for all BIM users.''* (A11, Design Architect, Mc1). However, A3 (Architecture Department Director, Mc1) went on to say that, *"The personality of some of our employees is to be special and exceptional, which was behind the emergence of an expert on BIM use within our team."*

5.3.5 Professional culture

Some respondents stated that professional's culture also influences the use of communication channels. Moreover, the diversity of the teams at Mc1 has also contributed in part to these changes. To illustrate this point, one respondent stated:

- "*For instance, if we are all in one open work area, then it is possible to speak face-to-face. If we are all together, then why do I have to send an email?''* (A6, BIM coordinator, recently left Mc1)

The researcher followed up on this statement by asking the respondent why he did not simply use email. He replied:

- *''Because this is our culture, if another employee is next to me, why not go and talk to him? This is better….''* (A6, BIM coordinator, recently left Mc1).

The majority of respondents who work in the same department at Mc1 commented that they fail to see the point of using email and prefer to speak Face to Face. This is discussed later in the communication protocol (see Section 5.5.1), along with the roles of leaders and managers on establishing communication protocols within their department (see Section 5.4.1).
On a number of occasions, when asked, Why do some employees prefer to communicate Face to Face instead of using the formal email system? The respondents referred to the influence of professionals' culture. Some of their statements follow:

- *''It is a matter of user culture. In the end, I don't have any evidence regarding the change orders that he asked us to write, and then he changed what he said earlier. Yes, the culture is influenced a lot.''* (A8, Architect, Mc1)

When asked why he came to this conclusion, he replied:

- *''I have worked on more than one project and with more than one project manager. Each one has his own culture. For example, some discuss changes, and request them in person. However, a few like to document everything by communicating with us via email.''* (A8, Architect, Mc1)

These statements suggest that because professionals' culture plays a role in this situation, differences in culture might influence the way that professionals communicate, and subsequently on the communication channels used. As one respondent stated, this is due in

part to Mc1's community of multicultural professionals. For example, one respondent referred to this factor:

- *''It's more about the cultural difference, which reflects on communication channel use.''* (A10, Design Architect, Mc1)

Moreover, the structural engineer stated:

- *"Let's say, as an example, seniors of [X nationality] most often request information via formal channels, such as email. In contrast, seniors of [Z nationality], for example, may ask questions in the car-park or in the elevator, etc."* (A13, Structural Engineer, Mc1)

Here, one could conclude that when the professional's culture at Mc1 is coupled with the influence of another national culture, the result is a dimension of impact which goes beyond that of the individual's. In addition, the workplace culture has an additional influence, i.e. the organisational culture itself. This effect is presented along with the communication protocol (see Section 5.5.1.1).

5.3.6 Resistance to change

Respondents referred to a few causal factors that lead to resistance at Mc1, including preference, familiarity, the presence of older employees, rumours, human nature, and other sub-factors (see Table 5-6).

Table 5-6: Resistance to change

Theme		Factor	Sub-factor	
Theme #1	Team members Characteristics	**Resistance to change**	**1. Preference Factor**	Faster means to communicate *(e.g. face to face conversation, telephone calls)*
				Familiarity factor *(e.g. hand sketching)*
			2. Familiarity Factor: Familiarity among employees, such as using CAD tools and hand sketches	
			3. The existence of older employees	Lack of knowledge and advanced computer skills
				Assistant requirements
			4. Circulated Rumours	
			5. Human nature, i.e. innate resistance to change	

5.3.6.1 Preference factor

Most respondents reported that they use communication channels based on their preference.

One respondent stated, *"I prefer face-to-face conversation rather than using email, servers,… etc"* (A11, Design Architect, Mc1). Such statements were common among respondents, which led the researcher to ask, Why most of Mc1's employees prefer to have FTF conversations.

Given this, the respondents who indicated this preference justified it by referring to the fact that it was a faster means to communicate since all one had to do was *"Just turn your face"* in order to convey a message. For example, one respondent stated:

- "*Of course, we have an email to speak with others. But, it's faster to speak with them directly."* (A14, Senior electrical engineer, Mc1)

In addition to this factor (i.e. faster means of communication), other factors drove the preference for some communication channels. The study results show that these factors include: 1) familiarity with the channel; and 2) the existence of an older generation of employees. This latter factor suggests that the general lack of advanced computer skills among older employees can lead them to depend on assistants. In addition, many older workers preferred to use hand sketches, even given the high capacity of BIM to generate 3D visualisation.

5.3.6.2 Familiarity factor

Another driver of resistance in adopting new or alternative methods is familiarity. Moreover, this familiarity often leads employees to prefer some communication channels over others. The three following statements highlight the link between resistance to change and familiarity:

- *''One of the main reasons behind resistance to change is the familiarity issue.''* (A4, Quality Control Manager, Mc1)

- *"I'm accustomed to this technique and method, so why should I change?''* (A4, Quality Control Manager, Mc1)

- *''In using communication channels it is easier for employees to use what they are familiar with.''* (A6, BIM coordinator, moved recently from Mc1)

In addition, some respondents characterised the familiarity as a constraint for successful information exchange during communication processes, specifically BIM work. As one respondent stated:

- *''One of the difficulties I face during BIM processes is that I have to exchange and share information so that other parties are familiar with it.''* (A10, Design Architect, Mc1)

In addition, it evidence from research results that the preference factor is due to familiarity, and findings prove that this is not limited to communication channels but also applies to software programs, such as CAD:

- *''CAD, as the basis of engineering programs, is indispensable. We call it the mother of all engineering programs…. With BIM, we use Revit and CAD is used less. But from time to time we return to CAD, which has a higher accuracy than other programs… and also, all of the staff are accustomed to CAD.''* (A9, Design Architect, Mc1)

Even at the client and contractor level, CAD documents remain the formal language of communication among stakeholders. Respondent A9 continued:

- *''So far, all of the files that are exchanged between stakeholders, either for government or private clients, are in CAD. Indeed, CAD files remain the formal language used in Saudi Arabia… the most widely used, the oldest, and far more developed than Revit.''* (A9, Design Architect, Mc1).

Hand sketches: A preferred tool within the BIM environment

In light of this, the study results also revealed that hand sketching is one preferred method that is used during Face-to-Face meetings (see Figures 5-1 to 5-3). One respondent commented:

- *''Oh yeah, habits [i.e. familiarity] definitely impact the way of I communicate…. I use a method that helps me absorb information. For example, I couldn't work without paper and pen and hand sketches."* (A1, Design Manager, Mc1)

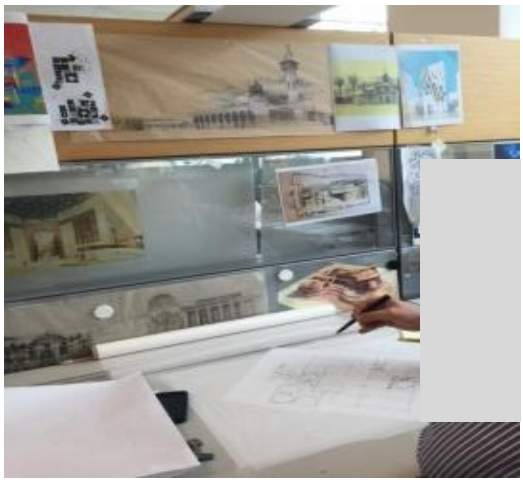

Figure 5-1: Hand sketches used illustrate a design concept

Despite the numerous benefits using BIM affords, at Mc1 hand sketching remains used for BIM-based projects (see Figures 5-1 to 5-5). However, this sketching is done far less than in the firm's former CAD environments. One respondent commented that, "…*hand sketches are used at the concept design stage and then gradually disappear at the later stages.''* (A4, Quality Control Manager, Mc1)

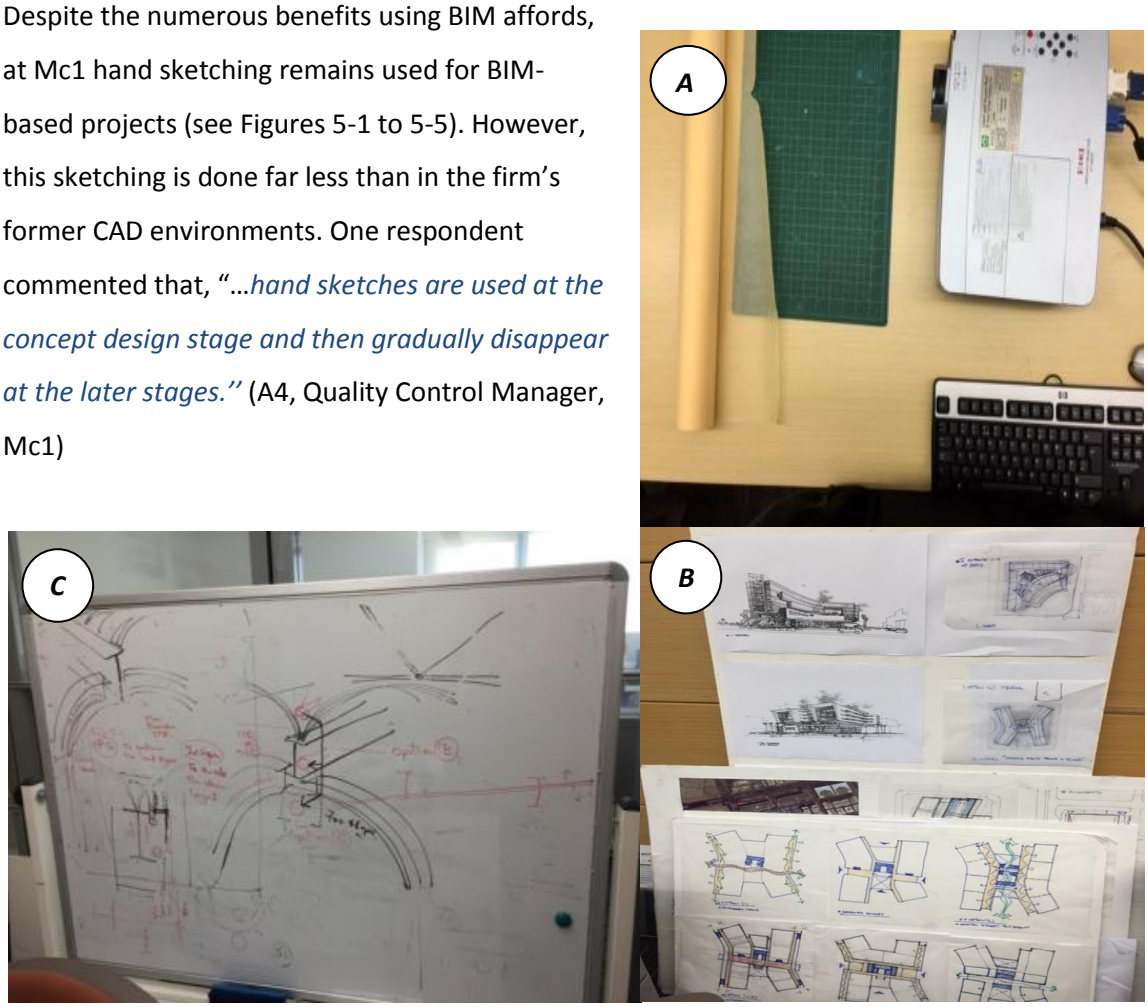

Figure 5-2: A,B and C show examples of sketches used in the office

However, some employees use hand sketching when working on design tasks. For example, one respondent indicated:

- *'' Usually, the explanation is done on paper. We have never used the computer, unless we intend to do the design. For reviewing purposes, I print drawings and place trace over them, then I modify them digitally, and go back to another print and sketch, and so on….''* (A8, Architect, Mc1)

Moreover, some respondents consider hand sketching to be a tool:

- *''… hand sketching remains as a supporting tool for us at meetings, in particular.''* (A10, Design Architect, Mc1)

Figure 5-3: An A0 sheet showing details, units, images and hand sketches

Interestingly, one respondent stated that hand sketches add a human touch to design projects (see Figures 5-4 and 5-5):

- *''… hand sketches are the spirit of a project, and CAD or BIM could never provide this spirit. The sense of the human touch should exist just as it is."* (A11, Design Architect, Mc1)
- *"Indeed, adopting BIM reduced the amount of hand sketching. But normally print BIM models and draw over them to add a human feel to the drawing.''* (A11, Design Architect, Mc1)

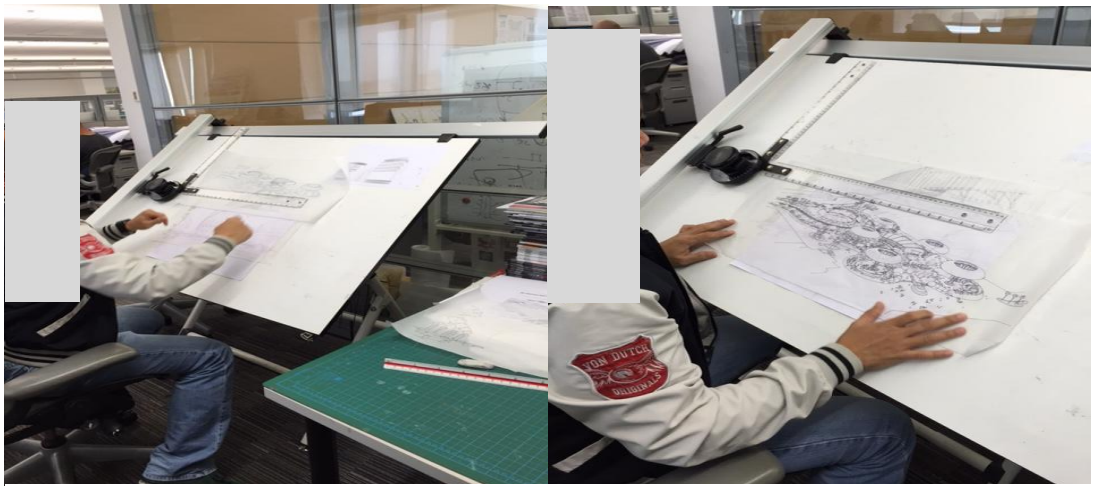

Figure 5-4: An employee hand drawing over BIM model image (as seen in Figure 5-5)

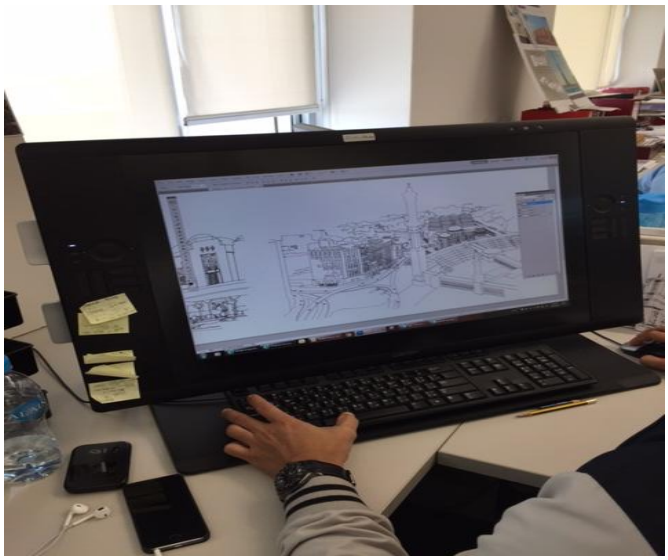

Figure 5-5: Adding hand sketches to a digital drawing

Here, these images show how one Mc1 employee uses hand drawings to add a human feel to his design work. These drawings are then scanned to the design project which produced through design drawing tools (See Figure 5-5).

5.3.6.3 The older generation of employees

The third factor that emerged from the analysis is the presence of an older generation of employees within Mc1's BIM work environment. The findings showed that in general, these employees react negatively toward changes in workplace systems. This suggests the question of why they resist these changes. Some respondents suggested causes such as basic human nature and the familiarity factor:

- *''The older staff… resisted implementing BIM for a while.. because human nature tends to resist change and or renewal.''* (A3, Architectural Department Director, Mc1)

- *"The older employees tend to block any new innovation by resisting change. In general, the innate human character is against the concept of change, which means that when people become familiar with something, and are then asked to use new methods or tools, they try not to change through resistance."* (A7, Senior Architect, Mc1)

While older workers in the office are typically those behind this resistance, some respondents stated that workplace rumours also contribute to this resistance. For example:

- *''At the earlier stages, there was some discomfort among the staff, particularly the older generation… because there were those who said that implementing BIM will lead to the dismissal of half the staff, and some said that it would reduce work hours.''* (A2, General Manager, Mc1)

As a result of this resistance to change, the general manager said that some staff were moved to administrative positions, and others who were near retirement were not trained in BIM.

- *''Not all of them [the staff] were trained in BIM; we transferred some to administrative positions… it is a mistake to invest training in every employee, especially those who will be retiring soon.''* (A2, General Manager, Mc1)

5.3.6.3.1 Assistant needs

Due to the highly technical nature of BIM processes, some new roles have emerged at Mc1 to manage project needs and requirements. Based on the analysis, some common roles that have emerged in BIM environments include BIM coordinators and BIM managers. However, due to the resistance of some older employees at Mc1 to adopt new processes and methods, all respondents were asked if there was a need to assign assistants to these employees to help them interpret BIM information. The respondents were largely in agreement in terms of the need to provide older employees with assistance. For example, one respondent commented:

- *'' Honestly, I'm one of those people who resisted the change…. Yes, requests for an assistant have happened a lot…."* (A4, Quality Control Manager, Mc1)

When asked what he needs assistance for, he replied:

- *''Normally, we ask for interpretation or explanation of unclear information."* (A4, Quality Control Manager, Mc1)

Which lead to an inquiry about who typically offers this assistance:

- *''Normally, the assistant is from the BIM department. For each department, there is a BIM coordinator who offers technical support.''* (A4, Quality Control Manager, Mc1)

This question was posed to one of the top management team members, who is among the older generation of employees:

- *"… this has frequently happened. Although I have already been trained in Revit, for administrative and technical issues there is a need for assistants such as the BIM specialist, who can show me conflict areas, for example.''* (A2, General Manager, Mc1)

This led the researcher to ask who the BIM specialist is:

- *''Normally, the assistant is the BIM Manager, who explains issues, and based on my experience as a project manager, the proper decision was made.''* (A2, General Manager, Mc1)

Another respondent, A3 the director of the architecture department, commented that:

- *''We are not zero knowledge about Revit use. All of our team members have had courses in Revit… but definitely not to the level of those who work with Revit day and night. Therefore, if they [the staff] can do in one day what might take me a week to achieve, then this is efficient."*
- *''I don't have to be an expert in BIM…. But at least, when a project is open in front of me, I can estimate the time required to complete the project*."

This led the researcher to ask the previous respondent about the person who assists him with BIM-related projects. He replied:

- *''The BIM manager or the BIM coordinator helps in explaining tasks."* (A3, Architecture Department Director, Mc1)

In sum, these responses suggest that some factors exist related to team member characteristics that influence changes in the communication channels used for BIM projects. These factors include the presence of rumours, documentation needs, level of knowledge and computer skills, the existence of competition, professional culture, and resistance to change. In addition, some sub-factors emerged that also contribute to these changes. Furthermore, Mc1's staff has carried over some more traditional tools for use within BIM work environment, such as hand sketches and CAD, which are due to personal preference, familiarity, and skill level. In addition, the study results revealed that leadership style also affects the choice of communication channels at Mc1, which is presented in the following section.

5.4 Theme 2: Leadership

This section discusses the leadership-related factors that influence communication channel use at Mc1, including: a) the general role of the leader; b) team member selection; c) technical issues; d) lack of sufficient information; and e) reward structures (see Table 5-7).

Table 5-7: Leadership

Theme		Codes (Factors)	Codes (Sub-factors)
Theme #2	Leadership	1. Leadership role (at department and project levels)	- Identify who, with whom to communicate, and how
		2. Team member selection	- Based on organisational culture established either by the leader/manager, or the organisation itself
		3. Technical issues	
		4. Lack of information	
		5. Reward structures	
		6. The design of the workplace	

5.4.1 Leadership role

There was unanimous agreement among respondents that their managers and leaders play a strong role in establishing and maintaining communication processes, both between team members and across departments. In light of this, this section discusses this role.

5.4.1.1 Identify who, with whom to communicate, and how

This section presents examples of the role that leaders and managers at Mc1 play in influencing the use of communication channels across contexts. Moreover, it highlights one aspect of the managerial/ leadership role in influencing the way in which identifying: who (sender); with whom (receiver); and through what (communication channels type).

One respondent comments:

- *''There is direction from the manager in terms of what to do, how to avoid (X), and to communicate with (X) person via this medium….''*. (A21, Design Architect, Mc1)

Similarly, one of the senior project managers commented:

- *''So I'm a project manager, and each project manager has his own approach to communication.''* (A15, Senior Project Manager, Mc1)

This led the researcher to pose the following question, which was not on the designated list: *Does this mean that communication channels might differ from one project manager to another, even at the same branch?* He replied:

- *''They follow the same protocol. However, they may decide to use text messages. I know somebody who texts….''* (A15, Senior Project Manager, Mc1)

While Mc1's all employees have to follow its communication protocol, this comment suggests that, at least in one department, the manager plays a significant role in influencing communication channels. In addition, a number of respondents mentioned some similar instances, such as:

- *''Our manager told me that our work environment is friendly, so… there is no need to send emails. Verbal communication is enough.''* (A5, BIM Manager, recently moved from Mc1)

In light of this, the researcher asked: *To what extent does the department manager play a role in communication with other departments?* He replied:

- *''The case now is different regarding the relationship with other departments. The manager usually insists on documenting everything and keeping him in the loop by cc'ing him in emails… because he wants to be kept informed and avoid any conflicts with other departments."* (A5, BIM Manager, recently moved from Mc1).

As a result, ineffective leadership has contributed somewhat to changes in the communication channels used, as one respondent confirmed:

- *''Ineffective leadership definitely plays a role; you can recognise who is a successful leader.''* (A8, Architect, Mc1)

When the researcher asked for clarification, he continued:

- *"The leaders took our design drawings and then disappeared. The funny thing is, they did not even send any emails to inform us about project updates. Furthermore, they do not allow me to attend formal meetings.''* (A8, Architect, Mc1)

In this regard, some questions were posed to the A1, (director of the design department), such as: *How many employees are in your department, and how do you communicate with them?* He replied:

- *''We have 35 architects. I communicate with them several ways: meetings, phone calls, in-person conversations, chatting over coffee, sitting on the beach, anything….''*
- *''Overall, when communication channels touch the senses [i.e. are tangible], communication processes are more effective. You feel it. I mean, the ability to deliver information is better."*
- *''The effectiveness of communication channels is classified by the senses [e.g. aural, oral, visual] , …. And the least effective [communication channel] is reading [i.e. emails]….''*

He closed the interview by relating an example:

- *"For example, what I could write in an email might possibly be explained in two words on the phone…. Likewise, what might be discussed in 30 minutes via video conference could possibly be concluded in few minutes if we all sit down face-to-face, and with higher productivity, as well."* (A1, Design Manager, Mc1).

In terms of using alternative communication channels such as social media networks for sharing project information, one respondent mentioned the use of the WhatsApp application:

- Part one*: ''Occasionally, we use social media to share project information among team members. For instance, we use WhatsApp…."*
- Part two*: ".…….However, the use of such applications is not for all projects... definitely not. This is determined by the project manager and his strategy.''* (A10, Design Architect, Mc1)

In sum, the above discussion suggests that managers and leaders play an influential role in making significant changes to communication channels. Furthermore, their role is not limited to their respective team or department performance, but rather they set up communication protocols to interact with other departments. In addition, these protocols vary from one leader/ manager to another. This has allowed for the use of social media applications, such as WhatsApp and Snapchat, as official communication channels. However, some managers and leaders reported that they decline to share information with some of their team members at formal meetings. In conclusion, the results show that managers and leaders can play an essential role in establishing communication channels that may differ from Mc1's official communication protocols (see Section 5.5.1).

5.4.2 Team member selection

With respect to the mechanism used to select team members, one senior project manager indicated:

- *"Now, maybe this is a good question for another office. Because at this office [i.e. Mc1], we are assigned staff—we don't select them. So, if it's a BIM team, then everybody's BIM. I have these people, but we also have... project managers here, technical teams there... a design team upstairs, a production team in [overseas branch name]. I'm given whatever I need."* (A15, Senior Project Manager, Mc1)

However, the selection mechanism differs from one organisation to another:

- *" In other offices, I mean to say [i.e. project manager]; him, him, him [select team members] "* (A15, Senior Project Manager, Mc1). This suggests that project managers at other offices select their team members, which is not the case at Mc1.

This discussion demonstrates that the mechanism used for selecting BIM team members varies from one firm to another. However, at Mc1, organisational culture plays an influential role in selecting BIM team members. As a result, at Mc1 this mechanism works either by selecting the members of the project team for the project manager or giving the manager the power to choose his own team.

5.4.3 Technical issues

The research findings revealed several factors that constrain employee performance in terms of communication processes and channels used for BIM-enabled projects. This section discusses these factors.

One fundamental technical challenge that employees face in their BIM-related work is the 'synchronisation process.' For example, a BIM coordinator commented:

- *"One of our biggest problems is that if two users synchronize a file on the server at the same time, the file will crash, and then we have to identify who has the most recent backup file for this work, in addition to the IT team backup."* (A6, BIM coordinator, recently left Mc1)

In addition, the senior architect identified another technical problem, which concerns two potential workflows for Mc1's Revit server: a) central models for used for smaller projects; and b) linked models used for large projects. He also identified a technical issue that Mc1's BIM users face during the 'synchronisation process period,' which is the time spent on the synchronisation process itself. For even small-scale projects, this process can take up to 40 minutes:

- *"On average, we work using linked models, as they is appropriate for large-scale projects with a large number of users. The main problem with Revit server is that as the number of users increases, you need very strong communication, which results in significant time spent on synchronisation. For instance, for small-scale projects, the time required for synchronisation can reach up to 40 minutes.''* (A7, Senior Architect, Mc1)

Along with the synchronisation issue, the research findings revealed another technical problem: team members often share their workspace remotely with related participants. Therefore, according to respondent A11, this contributes to some extent to changing the communication channels used, and stands in contrast to CAD processes. However, BIM technology does not allow side applications to be attached as a way of communicating minor or miscellaneous information and it also does not have the capacity to access the computers of other staff. In addition, respondent A11 suggested that Autodesk features applications that support the BIM users in this fashion:

- *''BIM systems do not support the necessary features that we had with the CAD system... namely, sharing workspaces [i.e. sharing screens]…. BIM is a very heavy system, and thus does not support assistive application, such as Team Viewer, contrary to CAD.''* (A11, Design Architect, Mc1)

The potential effect of shared workspaces on communication channels led the researcher to pose a question to respondent A11, (Design Architect, Mc1): *How might such a feature affect the communication channels used?* He replied:

- Part one: *''…easy access to another monitor allows us to directly address design issues and discuss how to fix them... all these actions can be done immediately when both of us are sitting at our own desks."*
- Part two: *"However, when using BIM, the scenario is different and more traditional. I go to him, or he comes to me. This has played a role on communication among professionals, no doubt… it is helpful.*" (A11, Design Architect, Mc1)

Yet another technical issue that some respondents identified are the disadvantages of using BIM, including the inflexibility of BIM design tools, Revit in particular, for creating design drawings. One respondent stated:

- *''One of the core disadvantages of BIM, as opposed to CAD, is inflexibility in easily performing design operations in the system. For example, you might want to design a certain form, but Revit imposes certain forms, which means it is impossible to design what you imagined. This is also a new tool, and not all of our users are experienced with it. In short, I am often unable to achieve what I imagine, and am therefore obliged to use available forms that only simulate the design that I was intended. This happens a lot.*" (A11, Design Architect, Mc1)

This disadvantage has led some employees to periodically revert to using CAD in order to achieve the desired design. In sum, this disadvantage of BIM (i.e. Revit), along with the lack of advanced computer skills of some employees may contribute to changing communication channels.

Finally, the BIM coordinator referred to another important technical issue: company infrastructure, specifically network speed and the hardware capabilities. This issue has resulted insufficient and ineffective processes for sharing information concurrently and in a timely manner. According to one respondent, along with insufficient infrastructure, the lack of qualified professionals to manage high-tech technology and their preference for traditional methods have contributed to changes in the communication channels used (see Section 5.3.6.1):

- "*In the Middle East at the moment, hardware and networks are not robust enough for data transfer speeds that would allow users to work concurrently. In addition, our employees are not qualified for work sharing, and they remain accustomed to CAD systems."* (A6, BIM coordinator, recently left Mc1)

These comments suggest that technical problems have contributed to changing the firm's communication channels from one context to another. In addition, respondents also stated that the organisation's leadership plays a role in terms of hiring qualified staff and providing sufficient technical infrastructure. If these are not forthcoming, some employees revert to the firm's previous system, and this will reduce the benefits which BIM can have on communication channels.

5.4.4 Lack of sufficient information

This section focuses on the significant influence insufficient information has on communication channels. However, it is first important to explain the reason for Mc1's increased requirement for communication processes, which is the need for required information. This need is largely due to the lack of information provision between team members because these provision processes may be unclear, incomplete, or incorrect. Subsequently, this often leads to the need to communicate through alternative communication channels, both verbal or nonverbal. To illustrate this influence, a number of responses are presented below:

- *''With BIM projects, important data is typically provided by the client and uploaded on the server. But how would one know about the existence of this data if we do not notify by sending a link for the data's location via email. Consequently, I have to find out where this data is on the server….''* (A8, Architect, Mc1)

This led the researcher to inquire: *How might this affect communication channels?*

- *''In practice, I leave my desk and pop up to see related team members to inquire about information and where it is located on the server. Normally, I do not leave their office until I have that information."* (A8, Architect, Mc1)

This comment suggests that the lack of information provision among project team members can shift their communication channels from using email to communicating in Face to Face. In addition, this issue has also had an effect in terms of changing the use of communication channels according to the purpose for the communication. Based on the research findings, this has resulted in using formal communication channels, such as email, and cc'ing managers for documentation purposes:

- *"Additionally, what has frequently happened is that I have to cc the department manager on emails…. this keeps me covered for any issues related to delays."* (Architect, Mc1)

The above comments reflect scenarios for those who work remotely with their teams. However, for those who work in the same area at Mc1, the scenario is slightly different:

- *''In this case, we all work in the same open area, so you just turn your head and ask verbally. Alternatively, if the person you need to speak with is not in yet, your ring him or walk through and ask. However, this depends on the type of the project and related information. Normally, those who work in the same area talk directly….*

There is no need for email, as we all work in the same department.'' (A10, Design Architect, Mc1)

- *''Why should I email my co-workers when it is faster to speak directly with them?''* (A14, Senior Electrical Engineer, Mc1)

The majority of the respondents who work in the same department shared similar attitudes in managing transfer of information; in these cases, the verbal conversation is the most common mode of communication. However, based on these comments, a lack of information is not the only factor that influences the communication channels used at Mc1; its leadership and design of its workplace also play a role.

5.4.5 Reward structures

The research findings revealed that the absence of reward structures influence not only the communication channels used at Mc1, but the level of motivation and exchange of experience and knowledge as well. When respondents were asked if reward structures play a role in altering their communication channels, the responses were typically something along these lines: "*What? What reward structures?''*.

After some clarification about the link between reward structures and sharing knowledge, one respondent stated:

- *''Let's talk, for example, about sharing knowledge with respect to technical issues. It is a part of our job, and we don't receive any kind of reward.''* (A9, Design Architect, Mc1)

Another respondent concurred:

- *"[Laughing] Maybe we have. However, honestly, during the last five years, I have not known about them."* (A10, Design Architect, Mc1)

And another:

- *"In [this country], and for my work at other firms I can say with confidence and without exception that none of them applied a rewards structure for their team members with respect to sharing knowledge."* (A6, BIM Coordinator,[recently left Mc1])

And another:

- *''Actually, I have not had any background in, or even seen a list of reward structures before. Honestly, the biggest reward for me is to learn how to use technology, and I become happier when I share my experience…. At this point, rewards do not happen at all, and will not be happening in the future.''* (A11, Design Architect, Mc1)

However, another respondent spoke about how Mc1 rewards its staff:

- *''We worked in CAD for more than 12 years. Consequently, all of us had the same level of expertise and CAD was common practice for us. In contrast to BIM, there is some difference in our skill levels…. So far, there is one staff member who is an expert and some who remain beginners. The expert was asked to become a BIM coordinator. However, some of his tasks were reduced, and he remained to support the team."* (A7, Senior Architect, Mc1)

When asked if Mc1 rewards his efforts, he (A7, Senior Architect, Mc1) replied:

- *''Yes, by reducing my workload. This is a kind of promotion…. Normally, the promotion system is linked to the salary scale…. At the end of the year, all of the employees' efforts are reported in an annual assessment form*."

Another respondent stated that sharing his knowledge with others *"stems from self-motivation.''* (A11, Design Architect, Mc1)

In conclusion, the presence or absence of reward structures may affect Mc1's culture in terms of employee performance. In light of this, the absence of a reward system at the firm contributed to the unwillingness of some employees to share their experience and knowledge, particularly with respect to BIM processes. In terms of this study, it is difficult to discern if communication channels were affected by this factor, as one has not been applied at Mc1.

5.4.6 Design of the physical work environment

Respondents were also asked to discuss additional factors that potentially influence the use of communication channels. A few respondents identified the role of workplace design. For example, one respondent stated:

- *''The design of the office environment allows people to communicate more quickly.*" (A6, BIM Coordinator, recently moved from Mc1).

When one respondent was asked why he uses Face to Face conversation instead of email, he replied (A10, Architect, Mc1):

- *"If the person I need to speak with is next to me, why should I use email?"*

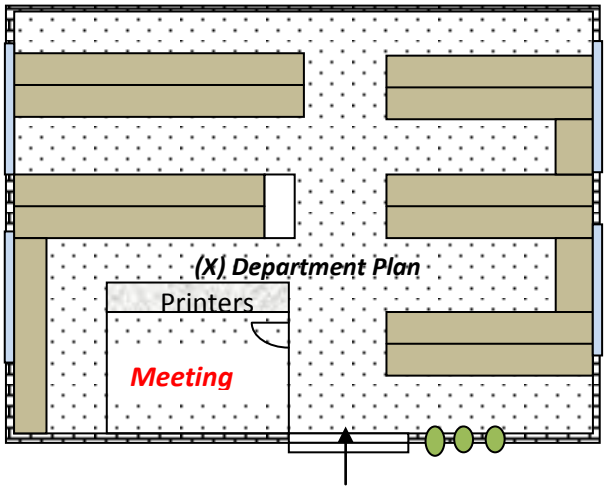

Figure 5-6: Typical department office floor plan for Mc1 (drawing by the researcher, 2016)

Figure 5-7 illustrates a typical office plan at Mc1. Department teams work in an open area along with their department manager. In addition, each department has a meeting room (see Figures 5-6 to 5-8).

As a result, at Mc1 the office layout plays a role in the communication processes among team members, some of whom questioned the need to use email when their colleagues are so close as discussed in Section 5.3.5: Professional culture) As a result, the design of Mc1's department offices appears to have reduced the need to use formal communication channels (e.g. email).

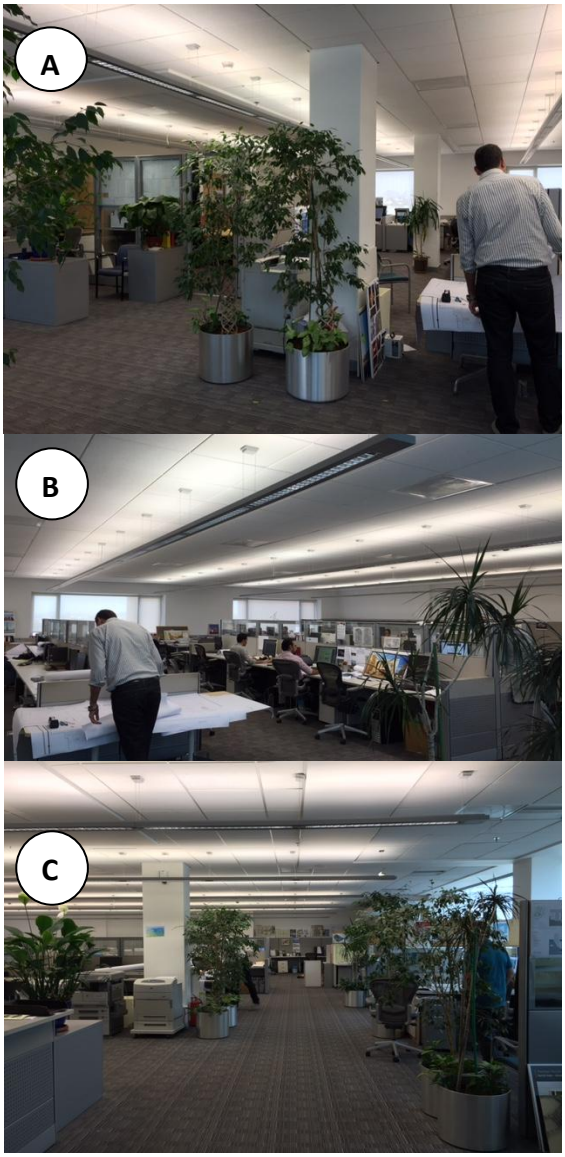

Figure 5-7: A,B,C: Internal snapshots for the work environment for (X) departmen

Figure 5-8: Internal snapshot for the x meeting room

In sum, this discussion suggests the role that Mc1's leadership plays in influencing the use of communication channels within BIM work environments. According to the respondents, these roles include identifying (who, to whom and through what); selecting the team member, technical issues; providing sufficient information to project participants; establishing a reward structure; and the design of the workplace. The final theme concerns the impact of communication protocols and BIM technology features on the communication channels at Mc1.

5.5 Theme 3: Methodology of Information exchange

This section presents the final theme that emerged from the interview data: the methods used for sharing information among BIM users. The data analysis showed the role that communication protocols and the technical benefits of BIM technology play in changing communication channels at Mc1. Table 5-8 lists factors related to this theme.

Table 5-8: Theme 3: Methodology of information exchange

Theme		Codes (Factors)	Categorizations	Codes (Sub-factors)
Theme #3	**Methodology of information exchange**	**Communication protocols**	a) Interior protocols used	– Organisational culture: ➢ An absence of communication protocol (CP) identification for team members; ➢ The role experience plays in using communication protocols; ➢ Communication channel selection based on project and user needs.
				– Rumours *(see Section 5.3.1)*
				– Leadership role (*see Section 5.4.1)*
			b) Exterior protocols used	– Contract forms
				– Project dynamics
				– Client type
				– Partner type
				– Partnership agreement
		BIM technology features		– Interoperability
				– Accessibility
				– Clash detection
				– Synchronization
				– Visualization

5.5.1 Communication protocols

This section presents in how communication protocols contribute to changing communication channels at Mc1. The data analysis showed that company protocols exist both for internal communication among office employees and for external communication among project parties.

5.5.1.1 Internal communication protocols

Communication protocols for internal use: Organizational culture

The study results revealed that organisational culture is one factor that influences the mechanisms used for communication channels within BIM work environments. This organisational culture reflects the rules and regulations applied to communication processes both within and across Mc1's boundaries. The findings revealed several factors that play a fundamental role in Mc1's organisation's culture, and several subfactors that influence the use of the firm's communication channels. These sub-factors include: a) the absence of identification of communication protocols (CP) for team members; b) the role of experience plays in using communication protocols, c) and the dependence on these CPs by staff based on the projects and users needs.

With respect to the first sub-factor, the absence of CPs, one respondent stated, *''One of the protocols in the HR manual at my former job at (x) firm, before moving to[Mc1], was on how to cc recipients according to their hierarchy in the organisation. This does not exist at all at [Mc1]."* In addition, the absence of such protocols at Mc1 *''…has caused some conflicts across the departments, and with the top management team.''* (A5, BIM Manager).

Furthermore, respondent A5's stated that the absence of CPs *''… is a common issue for almost all Saudi architectural organisations.''.* However, he went on to say that these protocols exist in *"…international firms, where the situation is different in terms of clarifying communication protocols [e.g. communication channels].''*

Similarly, two other younger respondents have referred to the absence of communication channel protocols at Mc1. For example, according to the Design Architect, who has three years of experience with BIM at Mc1 stated:

- *"No, I have not seen a communication protocols list since I've worked here—this the first time I've heard about it.''* (A10, Design Architect, Mc1)

Likewise, respondent A8 who has four years work experience, said:

- *"… my new phone was installed with my own extension number, and I got an email account. However, the firm never told me what communication methods I should use."* (A8, Mc1)

These statements suggest that Mc1's lack of clear communication protocols has affected the way that employees use communication channels. In addition, this has reflected negatively in how they interact with their peers, and has contributed to conflict within the organisation.

Communication protocols for internal use: the role of professional experience

The absence of communication protocols at Mc1 seems to play a fundamental role in influencing office communication practices. For example, one respondent stated:

- *''First of all, this company has 40 years of experience in the construction field. Definitely, there are protocols. However, when I started this job no one listed these protocols for me, so I learned them from experience. Junior architects work with senior architects, and they acquire their practices. Experience is the best teacher.''* (A7, Senior Architect, Mc1)

Similarly, the Design Architect said:

- "*Unfortunately, communication protocols are missing in our organisation. Everything there is learned through experience.*'' (A9, Design Architect, Mc1)

In light of this, the researcher asked respondent A9 how this experience was acquired at Mc1. He answered:

- *"… experience in using communication channels most often comes from either using the easiest way to communicate or the way that yields the most benefit."* (A9, Design Architect, Mc1)

Along with the absence of identified internal communication protocols at Mc1 and the role experience plays in communication channel use, managers and leaders are an additional influence on communication within or across departments (see Section 5.4.1). Furthermore, the absence of such protocols has not only caused conflicts in the firm but also somewhat

served to amplify the effect of workplace rumours. In sum, this suggests that the absence of interior communication protocols has contributed to changes in the communication channels used within Mc1's BIM work environment.

5.5.1.2 External communication protocols

Along with interior communication protocols, firms typically establish protocols for external communication. The research findings suggest that at Mc1 such protocols differ from context to context. According to some respondents, this diversity in communication channels is based on several variables (i.e. factors), many of which relate to project dynamics, including project needs, type and scale. Other factors concern clients, and still more relate to partners in terms of the nature of the partnership, the type and level of detail demanded, and partnership agreements. This section presents these factors with respect to their potential effect on Mc1's communication channels. In light of this, it is important to mention that all of these factors are typically addressed in project contracts. A number of respondent comments regarding these factors are presented here.

External communication protocol: Contract forms

With respect to the contracts, one respondent stated:

- *"Oh yeah, contractual obligations…. Communication protocols are usually contractually imposed on us."* (A11, Design Architect, Mc1)

External communication protocol: Project dynamics

Furthermore, contractual obligations differ from project to project:

- *''The selection of communication channels in our company is usually based on our needs…. They depend upon the project type, project scale, and the assigned team."* (A12, Sustainability Department Manager, Mc1)

Similarly, another respondent discussed the role project type can play in changing communication channels:

- *'If projects run smoothly, the communication protocols tend to stay the same all the way through, but if there are issues or if the project scope changes or other things change, the communication frequency protocols will change accordingly. So, yes, it's dynamic.''* (A15, Senior Project Manager, Mc1).

- *''I think it varies from project to project…. I would say that for a lot of projects it depends on project demands.''* (A15, Senior Project Manager, Mc1)

However, the usage rate for communication channels differs along with channel types with respect to project needs, type, and size. As one respondent stated:

- *''Concurrent communication methods and instant feedback among integrated disciplines have played a fundamental role in improving performance. However, it is very difficult to say that using BIM has decreased the time spent on communication. Indeed, this depends on to the nature of the project and its level of complexity. Certainly, communication duration differs from project to project.''* (A12, Sustainability Department Manager, Mc1)

External communication protocol: Client type

In addition to the previously mentioned factors, the research findings revealed the influential role project clients sometimes play on the communication channels used. According to the project manager, communication channel types are often covered in contracts, which usually stipulate face-to-face meetings. However, the frequency of these meetings (i.e. weekly, semi-weekly, etc.) can also have an effect:

- *''if the contract stipulates a frequency in terms of biweekly or weekly communication, then you have to follow what is in the contract…. but contracts differ depending on the client.''* (A15, Senior Project Manager, Mc1)

External communication protocol: Partner type

Furthermore, some respondents stated that the type of partner involved can also play a role in communication channels. One respondent identified typical partner types as contractors and local and international joint consultants. Some responses follow:

- *''… for some projects, the contractor requires us to use BIM, not the owner….''* (A13, Structural Engineer, Mc1).
- *'' We [Mc1] have a joint project with a British company. I'll travel soon to discuss joint regulations with them, and one of the fundamental issues is to clarify the communication protocols we will use…''* (A2, General Manager, Mc1)

Another respondent offered an example of the influence partners can play on communication channels:

- *''One contract with a consultant for a joint project was for [X] SAR… the company sent its core team, and sat with us until the project was delivered. One of their protocols was having a weekly meeting, and along with this, there was a contact person from both sides, and email was the main means of communication… everything was documented.''* (A7, Senior Architect, Mc1).

External communication protocol: Partnership agreements

As some research respondents indicated, for large-scale projects a number of multi-disciplinary consultants usually collaborate on an integrated project model. The following example suggests that additional protocols for communication processes usually exist between incorporated partners. He stated that these protocols are normally included as partnership agreements, which means they are not included in the main contract, and are often presented as memoranda of understanding:

- *''For example, one project owner is in Dubai, and the designer is in the UK, and the structural consultant is in America. However, this project is located in Riyadh. Thus, there is a partnership agreement for transmission protocols between the project participants for using certain cloud platforms, such as ACONEX, PMWeb, for managing project information."* (A3, director of the Architectural department, Mc1)

Another respondent confirmed that for these agreements, certain protocols are agreed upon for project management, *"such as, ACONEX or PMWeb* ". (A1, Design Manager, MC1)

5.5.2 BIM technology features

Aside from communication protocols, this section focuses on BIM technology features themselves and how they influence the mechanism used for communication channels. However, it is worth restating that one key question of this research study concerns three overlapping processes used by Mc1's employees: communication, collaboration, and teamwork: *Thus, regardless if a team uses BIM more for visualisation or for communication? Does it enhance the communication among actors, or does it extend or generate more gaps and keep them isolated?*

The following statements suggest that using BIM has added other forms of communication processes to Mc1's practice, including: 1) visual communication (i.e. visualisation); 2) communication across workplaces (i.e. accessibility); and 3) communication across different

software systems (i.e. interoperability); and 4) instant and concurrent communication (i.e. synchronisation). As a result, the researcher explored if and how these various forms of communication affected the communication channels used at Mc1. The following sub-sections present the respondents' views on this issue.

Respondents reported that the main BIM features they use are interoperability systems, accessibility, clash detection, synchronisation, and visualisation (see Table 5-9). This section addresses the implications of these features on the way in which Mc1's employees communicate by focusing on communication channel changes as one component of the communication process. These features stand in contrast to the factors discussed previously (i.e. Themes 1 and 2), which were addressed in the context of the workplace environment).

Table 5-9: BIM technology features

Theme		Factors	Sub-factor
Theme #3	**BIM technology features**	**BIM technology features**	▪ Interoperability
			▪ Accessibility
			▪ Clash detection
			▪ Synchronization
			▪ Visualization

BIM features: Interoperability

The study results suggest that implementing BIM brought a fundamental change to Mc1 in terms of the mechanism used for communication. One respondent stated:

- *''The main feature of BIM is interoperability, which means that we now have a common format for exchanging project data among different parties.*'' (A6, BIM Coordinator, Mc1)

Furthermore, this capability helped to improve the firm's 'thought process,' as two respondents stated:

- *''The way of thinking for professionals has begun to change, which means that their technical understanding of model components has improved as well."* (A6, BIM coordinator, Mc1).
- *"Indeed, there is no more need for A0 drawings (i.e. hard copies of drawings), nor the need for us to imagine what the product will be. What I once had to imagine is now visualised through project components in 3D."* (A1, Design Manager, Mc1).

BIM features: Accessibility

In addition, some respondents stated that the capability of BIM models to be accessed from multiple places using various support applications has dramatically changed their work and thus their communication channels. Some examples follow:

- *''The BIM has a significant feature that facilitates accessibility for multidisciplinary virtual teams from a central BIM server. Everyone can now access a shared model from everywhere.''* (A4, Quality Control Manager, Mc1)

In addition, the accessibility that Revit affords has also improved communication processes:

- *"One of the main features that BIM add is the Revit server. We now communicate through the server, so there is no more need to approach other engineers or employees and sit down, print sheets and talk, We now do this using the Revit server by communicating directly through the server. "*(A12, Sustainability Department Manager, Mc1)

One respondent also mentioned Autodesk 360, a cloud storage application:

- *"There is an application called Autodesk 360…. You can use it to review Revit models from anywhere, anytime…..You can have a look at a model, submit comments, and send it back.''* (A6, BIM coordinator, Mc1)

BIM features: Clash detection

The capability of BIM to detect clashes has also influenced Mc1's communication channels in that it has increased the need for communication. Previously, clashes would appear in the earlier stages of the design process. One respondent commented:

- *'' BIM has increased the need for communication.''* (A1, Design Manager, Mc1)

This led the researcher to ask why this occurred. The respondent clarified:

- *''BIM identifies these clashes. With CAD, clashes often occurred but were unknown to us.''* (A1, Design Manager, Mc1)
- *"Using BIM through Navisworks helps to detect and identify clashes across project data."* (A6, BIM coordinator, Mc1)

Clash detection also allows employees *''to address problems that appear straightaway, which makes the decision-making process faster and more accurate."* (A6, BIM Coordinator, Mc1).

The respondent continued: *"With BIM, communication takes place in different ways. You can send a request, do a cloud review, write comments, and grant permission to address project issues.''* (A6, BIM coordinator, Mc1).

In addition, one respondent commented that all of these BIM features *''reduce the need for team meetings…. Normally, we met when we had a problem. Actually, we had most of our meetings to address problems."* (A11, Design Architect, Mc1).

Furthermore, clash detection also tends to reduce conflicts among project participants, as one respondent stated::

- *''Now that clashes have become more obvious, solving them happens more quickly. Moreover, as a result, personal conflicts between the participants have reduced.''* (A11, Design Architect, Mc1)

Moreover, the results suggest that this feature also reduces the time spent waiting for project participants to set up meetings:

- *"This means that there is no more need to wait for a FTF meeting … to discuss the issues which have emerged. There is no need either for everyone then to return to his workspace to study this issues; or to decide whether it is an issue, or not"*.

These comments reflect the more traditional scenario of meeting to review drawings to determine how to solve project issues. In contrast, with BIM, *''… the issue is crystal clear. So, whether it is my mistake or someone else's, one of us admits it and we solve it."* In addition, the respondent stated that, *''… the ability of BIM to detecting drawing clashes has significantly reduced conflicts.''* (A11, Design Architect, Mc1).

Furthermore, another respondent stated that, *"… when I work on a [BIM] model, I can detect and avoid possible clashes. We have become more aware through the design process about potential clashes."* (A6, BIM coordinator, Mc1)

BIM features: Synchronisation of design and construction drawings

In their interviews, respondents frequently referred to 'synchronisation.' Although this benefit plays a role in improving the design process, the question remains if this process affects the use of communication channels. One respondent stated:

- *''One of the core features of BIM is that team members are simultaneously updated with project-related information. This stands in contrast to using CAD, for which the MEP, and the structural team work separately… and then coordinate by viewing all of the drawing sheets together."* (A12, Sustainability Department Manager, Mc1)

This comment suggests that BIM's capability to synchronise the design process not only reduces the need for design coordination sessions but also eliminates the need for drawing sheets as physical communication channels.

Respondents reported that at Mc1 the majority of project-related communication runs through BIM technologies, rather than around a table. One respondent stated:

- *''BIM has significantly improved the information exchange process among employees. Let's say, when I draw a column, the entire team sees the same model at the same time, and is updated on any changes. So, we all see the changes, and are able to evaluate the attributes assigned to this column. Not only that, we are all able to discuss and request information and the authority to make changes."* (A10, Design Architect, Mc1)

Finally, in terms of communication channel changes, one respondent stated: *"Changes have definitely occurred. We now attend meetings fully informed in advance about information and recent problems."* He continued, *"We are now instantly aware of changes, clashes, and related issues.''* This, in turn, has contributed to "*shifting some of the communication tasks from the meeting table to the digital realm."* (Design Architect, Mc1)

BIM technology features: Visualisation

From the respondents' viewpoint, the capability of BIM technology to visualise design drawings in 3D is considered as a core feature for their practice. This is largely because this feature has played a role in improving their understanding of design projects and absorbing design errors, which subsequently helps improve the end product.

All of the previously discussed BIM features are those that respondents most frequently addressed in this study. This section presents the findings with respect to the effect of the 'visualisation' feature of BIM systems on the communication channels used at Mc1.

For example, one respondent commented:

- *''The use of communication channel types is the same for almost all of our projects. But, for BIM processes, their usage rate has decreased. Certainly, with the Revit tool I'm able to see everything that is done on the model by the team. Thus, there is no need to sit down with the relevant engineers.''* (A7, Senior Architect, Mc1)

Similarly, another respondent referred to the BIM visualisation feature that allows employees to visualise design drawings in 3D. This helps in identifying related issues and resolving them early.

- *''The most beneficial aspect of BIM is that issues and clashes are understood and visible to team members…. This has contributed to reducing wasted time and effort. This is in contrast to the traditional method [i.e. CAD], in which one works separately, no one cares about what they are doing, and at the end, being shocked about any massive errors in the drawings. Now, we are in an integrated process with our design partners.''* (A10, Design Architect, Mc1)

One of the sub-questions that was posed here was: *Does BIM increase or decrease the communication period?* The department manager said:

- *''Let tell you something: communication is smoother, and we communicate through the server. This has reduced wasted time spent on explaining design-related issues such as clashes between beams and ductwork…. Because everything is visual, I can see and describe any issues and help to try to find alternative solutions. But, definitely, instant communication has been improved as an inevitable result of increasing the level of required detail.''* (A12, Sustainability Department Manager, Mc1)

A similarly, another respondent commented:

- *The 3D visualisation feature has reduced unwanted communication channels. Just imagine, before I had to leave my desk and sit in on meetings for two to three hours in order to explain issues to the engineers. Now, the scenario is different— what I need to clarify is visualised, and we can see and explain issues in five minutes."* (Department Manager, Mc1)

Moreover, with respect to the visualisation benefits of BIM, one respondent indicated that they are not limited to shared teams having a better understanding of the process, but also

for clients in terms of *"having a better visualisation of projects before they are built''* (A5, BIM Manager, recently left Mc1). As a result, design decisions are made faster than ever before.

In sum, along with the visualisation benefits of BIM, Mc1's employees have reduced the need for unwanted communication channels they employed when using CAD (i.e. face-to-face and group meetings, design worksheets, exchanging emails, telephone calls, etc.). The ability for design professionals to visualise a design product in 3D before it is built has benefited clients and lower-skilled employees as well. Subsequently, project decision-making processes have become faster, but more importantly, the process is more appropriate for integrated design projects when compared to the traditional CAD system.

5.6 Summary

This chapter presented the findings that emerged from the interview data analysis. Based on this analysis of this data, three central themes: team member characteristics, leadership, and the methodology of information exchange were identified with respect to the effect of BIM use on changes in communication channels. In addition, the thematic analysis showed that the primary factors that influence changes in workplace communication channels across contexts were rumours within the work environment, resistance to adapt to new technologies and systems, types of communication protocols applied and character of leadership. In addition to these factors, the technical capabilities of BIM technology to share information among employees also played a role in changing the communication channels. Further discussion of these findings is presented in Chapter 6.

Chapter 6

Discussion

Chapter 6. Discussion

6.1 Introduction

This chapter discusses the results presented in Chapter 5 regarding 'what' happened to the communication channels at Mc1, and 'why.' These findings were categorized into two groups: G1, organisational environment characteristics; and G2, the technical characteristics of BIM technology (see Figure 6-1). In addition, under these two groups, five main themes are presented as the factors that influenced changes in the mechanism used for communication channels at Mc1. Furthermore, interrelationships were found between some of these factors, and those interrelationships that emerged either within or across other themes are discussed and referenced here. Moreover, when possible, this chapter also addresses the extent to which these findings are consistent with the literature.

Figure 6-1 shows the main categories (G1 and G2) and primary themes (T1 to T5) that emerged from the data analysis. The scope of the study, changes in communication channels

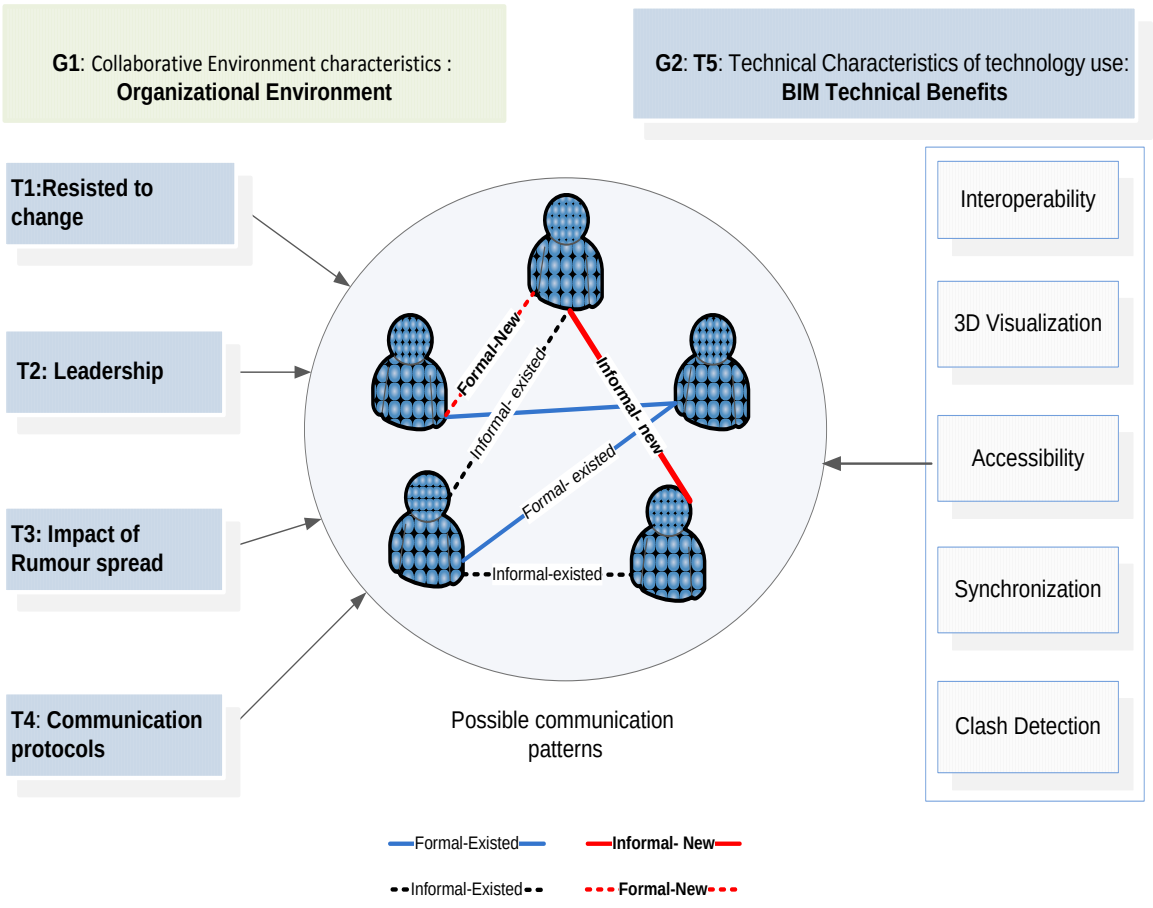

Figure 6-1: Summary for the Categorizations of the reserch findings, five main themes

at Mc1, is depicted at the center, and shows possible communication patterns (e.g. formal, informal), and any changes that resulted from BIM implementation. This figure also presents the research concept in a simplified format as a diagram of the impacts on communication channels for the two main groups. Along with presenting the research findings, this chapter discusses research limitations that revolve around additional dimensions (e.g. influential factors) that were anticipated to emerge based on the literature review, but did not appear in this case study research. Nevertheless, these factors have the potential to change communication channels, so it is necessary to consider them in future studies.

6.2. Group 1: Organisational environment characteristics

Chapter 5 reported that influential factors emerged in this study that relate to the effect of organisational environments and the technical benefits of BIM on communication processes and subsequently on the mechanism used for selecting communication channels. However, a comparison of these results to the BIM literature suggests that the influential factors that emerged relate to: 1) people (e.g., older employees, lower-skilled professionals, etc.); 2) processes (e.g. communication, leadership, etc.); and 3) the workplace environment itself (e.g. lack of trust, presence of rumours, etc.). However, this study did not seek to classify emerging influential factors as some of the BIM literature does (see Chapter 2, Section 2.3.3). Furthermore, such classifications in the BIM literature tend to mirror collaboration theory classifications in terms of their consideration as the main determinants of the success of collaborative processes. However, based on the core aim of this research, which is exploring 'what' happened to the communication channels at Mc1 after implementing BIM technology, and 'why', this section discusses these influential factors and their effects; by presenting the four main themes involved in the organizational environment at Mc1.

6.2.1 Theme 1: Resistance to change

The study findings suggest that the factor of 'resistance to change' played a critical role in influencing the communication channels used within BIM work environments at Mc1. Employee resistance to change is a commonly known phenomenon that is discussed in the relevant literature. For example, Ebrahim et al. (2009) considered this to be one of the main challenges to successful virtual teamwork processes. However, the analysis showed that within the BIM environment at Mc1, resistance to BIM by various employees in terms of adopting new communication modes was caused by diverse factors. In addition, this study

revealed associations between these factors and either resistance or promptly changing to new communication channels. In light of this, the influential factors behind this resistance include preference, familiarity, speed, employee age, a lower relative level of skill and knowledge, workplace design, and presence of rumours. The following subsections discuss each of these factors.

6.2.1.1 Resistance to change: Individual Preference

Chapter 5 discussed that the thematic analysis of the factor 'resistance to change' showed that the selection and use of communication channel modes within the BIM work environment at Mc1 was influenced by employee preference. Thus, some employees at Mc1, either individually or as a group, found that the communication channels they used varied across context, despite having training in the use of BIM tools (i.e. Revit). This particular result supports Watson-Manheim and Belanger (2002), who showed that that individual preference affects the choice of communication channels across contexts. The authors' unit of analysis for this case study was two information technology companies. In this respect, the current study showed that for BIM work environments at Mc1, some specific communication channels are preferred, including: 1) face-to-face (FTF) meetings as one-on-one conversations or group meetings; and 2) the use of hand sketches either during these meetings or for adding a human touch to final design products (i.e. BIM models).

In light of this, the study findings are consistent with the literature on communication (e.g. Gabriel and Maher 2002), teamwork (e.g. Ebrahim et al. 2009), and collaboration (e.g. Dossick and Neff 2011) in terms of FTF conversations as a preferred communication channel within collaborative work environments, regardless of the technologies applied . FTF was the preferred channel, irrespective of the context of these studies, or cultural differences as shown by the Eckert et al. (2005) study.

Furthermore, the study results are also consistent with those of Powell et al. (2004), in that hand sketching can serve as an important tool during meetings to streamline the process of information exchange. Some researchers consider the main strategy in BIM design review meetings to be ''visual language'' (Homayouni et al. 2010: 784).

Along with preference, the study results showed that it has exceeded the concept of exchanging the communication channels to be discovered that occasionally, employees returned to using previous design tools (i.e. CAD) instead of Revit, for example. This suggests

that preference could be one of the most influential factors on the success of BIM implementation at Mc1 in general, and also the primary cause of employee resistance. In addition, the results show that the influence of preference was not limited on the communication channels used, but extended to software applications (i.e. Revit) as well. This suggests that preference affected the use of applications (i.e. Revit via BIM, reverting to CAD) across contexts within one work environment, and in some cases resulted in significant changes in the types of the communication channels used that each application provides.

The analysis also found that CAD is still the preferred design application (i.e. preferred formal language of communication) for project parties in the KSA. This partially explains the presence of two different methods for generating design drawings within a single work environment at Mc1. Consequently, switching between these two approaches to execute design work has influenced the type of communication channels used at the firm. In addition, the findings showed that differences in preference between employees varied within a single work environment. As a result, some respondents at Mc1 reported that they often use certain communication channels that correspond to the preferences of their colleagues. Furthermore, the preferred formal communication mode for exchanging design information (i.e. for final submissions) for the majority of Saudi clients is CAD drawings. This finding is consistent with those of many other Saudi studies, and stands alongside their consideration of preference as one of the main challenges successful BIM implementation that firms face (Al Soliman 2012).

6.2.1.2 Resistance to change: Familiarity

The results also showed that another influential factor that drove resistance to change at Mc1 was familiarity. In addition, the findings revealed a strong connection between the factors of familiarity and preference. Employees working on BIM-based projects reported that they prefer to use the channels they are familiar with. In addition, the analysis showed that both preference and the familiarity factors resulted in resistance from employees in terms of changing the communication channels they use. Importantly, in terms of using hand sketches as a preferred communication mode, the study findings showed that this practice is not only considered valuable during FTF meetings, but also that some respondents maintained that this adds a 'human touch' to BIM models, i.e. it reflects *"the spirit of the project."*(A11, Design Architect, Mc1)

6.2.1.3 Resistance to change: the Speed factor

Another factor that influenced resistance to change and a reason behind employee selection of certain communication channels is a 'faster means of communication' (i.e. speed). For example, the study results revealed that rather than taking advantage of the communication benefits that BIM provides, such as making inquiries in Revit, pointing out issues in integrated models, and exchanging information via a Revit server, some employees at Mc1 prefer to make inquiries FTF. As some respondents reported, the latter channel is a faster means to communicate. In addition, at the level of using formal communication channels such as email, some respondents reported that verbal communication (e.g. FTF communication, telephone calls, and video conferencing) is easier and faster than writing email. Again, this underscores the fact that speed influences the justification of some respondents' resistance to adopting the new communication channels that BIM provides.

6.2.1.4 Resistance to change: Workplace design

Another factor emerged from the data analysis that might contribute to resistance to change at Mc1: workplace design. The researcher's observations of the design of various departments at Mc1 showed that the convergence of one workspace (i.e. unit) with the lower designed partitions, along with layout of the department, with all team members from related disciplines in one place. From the researcher's point of view, this arrangement facilitated FTF communication and reduced the need for more formal communication modes. In addition, the presence of department managers and the availability of facilities such as meeting rooms and plotters within each department might have contributed as well. This finding is consistent with Penn et al. (1999), who showed that spatial configuration can affect the movement patterns of users and directly influence their communication frequency. However, in addition to this evidence from the literature (e.g. Penn et al. 1999) which support the research result of this thesis on the influential role workplace design can play in communication patterns, some interview respondents in this study reported that professionals culture at work also contributes to resistance, regardless of proximity.

6.2.1.5 Resistance to change: Presence of an older generation of professionals

In addition to the factors discussed above, the study results revealed that the presence of older employees within BIM work environments at Mc1 plays an active role in resistance to change. Consequently, this result supports the findings of previous studies with respect to resistance (e.g. Alnaser and Harty 2016; Homayouni et al. 2010). The respondents identified several factors that contribute to this resistance, including: 1) it is basic human nature to resist change; and 2) older employees are accustomed to certain existing communication channels (e.g. *"We are familiar with this, why do we have to change?"* (A4, Quality Control Manager).

However, the pilot study findings (see Chapter 4) revealed that employee resistance to new technologies (i.e. BIM) at Mc1 was also partly due to fear of losing their positions. In line with this fear factor, the main case study results showed that some older professionals at Mc1 employ resistance as a way to secure their current positions. In addition, the findings revealed that resistance by older staff members was evident among some who play essential roles at Mc1 (e.g. department directors), which resulted in the need for assistants, who were either BIM managers or BIM coordinators. However, regardless of what role these assistants might play, the researcher concluded that this practice contributed to some extent in changing the communication patterns at Mc1, and subsequently the type of the communication channels its employees use. Consequently, resistance by some employees within the BIM environment resulted from their lack of advanced computer skills as well as fear of losing their positions. In addition, the findings show that Mc1 does not wish to invest training in employees *"who will be retiring soon''* (A2, General Manager), which may also have contributed to resistance.

6.2.1.6 Resistance to change: Rumours about BIM benefits

The data analysis revealed the effect of rumours spreading in the workplace about the adoption of BIM to be another influential factor. This result showed a strong association between rumours circulated between professionals and their resistance to change, particularly in the context of the advantages and disadvantages of implementing BIM at Mc1. This suggests that rumours played a role in this resistance (see Subsection 6.2.3).

In sum, these results suggest that resistance to change is one of the fundamental influential factors for employees at Mc1 in not taking advantage of the new communication channels provided by the organisation in general, and by BIM in particular. Despite BIM's capabilities and features, employee preference often led to the use of FTF communication as the channel of exchanging design information. In addition, resistance to change is one of the factors that contributed to the emergence of the 'substitution phenomenon' for different communication channels. Moreover, this resistance is also due to other factors, such as: 1) familiarity; 2) the presence of the older employees; 3) workplace design; 4) speed factor; and 6) the impact of rumours.

6.2.2 Theme 2: Leadership

This section discusses leadership related factors that influenced the communication channels used at Mc1. The study results showed that these factors include: 1) the role of leader and managers; 2) a lack of mutual trust; 3) technical challenges; 4) a lack of information provision; and 5) a lack of a reward structure. The following subsections explain the influence of these factors.

6.2.2.1 Leadership role: leader/manager roles

There was unanimous agreement among the research respondents that leaders and managers play a strong role in influencing the communication processes both between team members and with various departments. This section discusses these roles, which include: 1) identifying who, to whom, and through what (i.e. communication channels; and 2) selecting appropriate collaborators.

6.2.2.1.1 Leadership role: Identifying who, to whom, and through what

The research findings verified the critical role that leaders and managers play in influencing the communication channels used across contexts at Mc1. Specifically, the results showed that managers and leaders affect the communication process by specifying who (i.e. senders), to whom (i.e. receivers), and through what modes (i.e. communication channels) information is communicated.

Along with Mc1's communication protocols (see Section 6.2.4), the data analysis showed that each leader/manager at the firm takes his own approach to communicating with his team

members and across various teams and departments. A number of respondents reported specific examples of this phenomenon, including leaders and managers limiting the communication processes within one department to FTF conversation, with no need for using email. As one manager explained, this was because Mc1's workplace is *'a friendly environment'* (A5, BIM Manager). However, regarding communication with other departments, the research findings revealed that this manager required his team to document communication using email, and to cc him on all correspondence in an effort to avoid any potential conflicts with other departments.

One interesting finding that emerged from the data is that social media platforms, such as WhatsApp and Snapchat, are sometimes used in BIM-based projects at Mc1. However, their use varied from team to team, largely due to the approach is taken by their respective leaders/manager, with some considering the use of social media as informal, and others using it in a formal way to communicate with their team members, based on client demand.

In this respect, the results also showed that some managers also prevent their project team members from attending formal face-to-face meetings. However, from the perspective of Amabile et al.'s (2001) collaboration theory, the role leaders play in holding regularly scheduled FTF meetings, along with the successful use of their team's capabilities, can result in facilitating communication processes and project success. Control of what is allowed and what is prevented reflects the extent to which leaders/manager affects communication channels within collaborative environments.

In sum, the research results showed that some social media platforms are used as official communication channels at Mc1, and leader/manager sometimes prevent their team members from attending formal face-to-face meetings. As a result, the findings suggest that both leaders and managers at Mc1 play a strong role in establishing their own communication protocols for their teams that exist alongside their organisation-wide protocols, which influenced the use communication channels across contexts.

6.2.2.1.2 Leadership role: Selecting appropriate collaborators

With respect to the mechanism used for team member selection at Mc1, the data analysis showed that the role leaders played in this process in selecting BIM project teams was largely absent. In contrast to the literature on communication, collaboration and teamwork, Maccoby (2000) stated that one of the four functions of effective leaders in successful

organisation is selecting appropriate talent, and Amabile et al. (2001) collaboration theory emphasizes the selection of appropriate collaborators and developing their skills. In terms of this study, the respondents reported that in contrast to other firms, at Mc1 the organisation selects team members, and that this process is governed by the firm's organisational culture. However, Amabile et al.'s (2001) cross-profession collaboration theory states that one of a leader's responsibilities in successful collaboration processes lies in is selecting appropriate collaborators. Here, the research findings suggest that at Mc1 the leadership has proved inadequate in selecting appropriate team members. Thus, it is difficult to ascertain to what extent the absence of the leadership role in selecting effective project team members affected communication channels at Mc1.

6.2.2.2 Leadership role: Lack of mutual trust

The research findings also revealed that the selection of communication channels between sender and receiver was often based on the level of shared mutual trust. For example, one study respondent frequently mentioned that his *"work environment is a friendly environment"* (A5, BIM Manager), with no need to use email within his department. This reflects to what extent leaders play a role at Mc1 in building the trust among employees, in this case limiting the communication mode to verbal interaction. It is evident in the literature that building trust can improve communication processes among various professionals (Sclater et al. 2001; Eckert et al. 2005; Powell et al. 2004; Ebrahim et al. 2009; Maccoby 2000), and some researchers consider trust to be reflection of leadership effectiveness (Fjermestad and Ocker 2007; Maccoby 2000).

However, the results of this study have not clearly shown the trust-building leadership strategies that are commonly mentioned in the literature. For instance, holding FTF meetings at the beginning phases of design projects (Dossick and Neff 2011; Powell et al. 2004; Eckert et al. 2005; Amabile et al. 2001) have been shown to foster friendships and build trust among collaborators (Sclater et al. 2001; Paré and Dubé 1999). At Mc1, examples such as emphasising that the work environment is an atmosphere of trust, denial of rumours, and limiting communication channels to FTF conversations might have played a role in building trust. However, the research findings also showed that in an attempt to avoid conflict, the leader in question specified email as the formal means of communication for documentation purposes.

However, Watson-Manheim and Belanger (2002) found that a lack of trust can contribute to increasing the use of email for documentation purposes. Consistent with this study, the current study showed that requiring the leader/manager to be cc'd on all emails is one common communication protocol used at Mc1. In addition, the data analysis revealed a connection between documentation needs within or across different departments and the level of trust within BIM work environments.

In sum, the lack of mutual trust among professionals at Mc1 led to replacing an informal communication channel (i.e. FTF conversation) with a formal one (i.e. email) in order to document communication processes and their content.

6.2.2.3 Leadership role: Technical challenges

A number of technical challenges emerged from the data analysis that influenced communication processes and thus channels at Mc1, including: 1) synchronisation process challenges; 2) ineffective and insufficient organisational infrastructure; 3) unqualified employees; 4) ineffective leadership; 5) inflexibility of BIM design tools; and 6) the lack of a remote access tool.

At Mc1, BIM synchronisation processes are conducted through a server, and the research results revealed that information might potentially be corrupted if two users were to synchronise a model simultaneously. In addition, even for smaller projects, the time spent on the synchronisation process itself can reach up to 40 minutes. However, the results have not clearly shown if these technical challenges were due to ineffective organisational infrastructure, lack of professional skill, or to the BIM technology itself. However, for this study, all of these technical challenges were deemed influential factors, as they were found to impede the process of design information exchange among professionals via the specified communication channels. This, in turn, led some employees to use alternative channels to communicate.

Another technical challenge the research findings uncovered was the ineffectiveness of Mc1's organisational infrastructure in managing these high-tech capabilities. The data analysis showed that the firm's insufficient network speeds and hardware's capabilities contributed in part to ineffective communication processes for simultaneously and quickly exchanging design information. This result is consistent with Maier et al. (2009) and Sclater et al. (2001),

who found that these technical barriers can impede communication during the design process. Therefore, as Brennen et al. (2007) found, improving technical support lead to improved communication processes.

In addition, the results showed that employees who were unqualified in terms of interpretation skills and knowledge in effectively managing high-tech technology and their preference to use previous systems (i.e traditional ways of working) contributed to changing the communication channels used at Mc1 (see Section 6.2.1.1). In addition to this, and at the discussion meeting for the BIM team project, the research findings are consistent with the study of Dossick & Neff (2011) in terms of continuing to use the hand sketches (i.e. a traditional way) by uses tracing paper on top of rendered images. In addition, the respondents indicated that ineffective leadership also played a role in terms of a lack of providing qualified staff and sufficient infrastructure that is in line with Mc1's technology capabilities. This led some practitioners (i.e. older employees and lower-skilled professionals) to revert to Mc1's previous communication system. In turn, this behavior might reduce the advantages of BIM in exchanging design information.

Contrary to expectations, in terms of executing design concepts, the results showed an inflexibility of BIM design tools (i.e. Revit) in achieving what designers at Mc1 imagine. For example, some respondents indicated that this inflexibility is a core weakness of BIM technology, and one that in some cases led them either to use the forms that BIM provides to simulate their designs or return to using CAD. As a consequence, these shifts between design platforms resulted in altering the communication patterns for exchanging design information and thus changing the communication channels used at Mc1.

In addition, an unexpected finding was the suggestion that Autodesk should develop a remote access tool. According to respondents, such a tool could enable BIM users to access and share their workspaces (i.e. screens) remotely, as the CAD platform allows. This absence of a remote application in BIM software was found to contribute to changing the communication processes, patterns, and eventually channels at Mc1. Some respondents indicated that a remote tool could improve communication processes and virtual teamwork. This finding is consistent with Ebrahim et al.'s (2009) study on the importance of remote access and control technology in improving virtual team performance and the role the team leader plays in selecting appropriate technologies.

Overall, these technical challenges influenced the communication channels used at Mc1, which is consistent with Watson-Manheim and Belanger (2002), who also identified these challenges as factors in changing communication channel use.

6.2.2.4 Leadership role: Lack of information provision

The research findings also revealed that a lack of information provision impeded Mc1's communication processes. The often unclear, incorrect, and incomplete information provided to the BIM design team resulted in an increase in communication, along with changes in the communication channels used. While one of BIM's main features is to provide information that is easily accessible, the results showed that Mc1 still lacks an adequate information provision system for its employees. In this respect, the findings revealed two different scenarios in the case study research that showed how this lack of information provision eventually affected how Mc1's employees communicate with each other. This depended on whether employees were working in the same physical environment, or at a distance. For instance, Although BIM design information is located on a server, the findings showed that some employees who were working at a distance still requested and received information via email i.e. links to the location of information on the server. Or, failing this led some individuals to leave their desk to find the missing information. This is consistent with Eckert et al. (2005), who found that recipients either returned messages to the sender requesting more information, or found the missing information through other sources.

However, if incidents of lack of information occurred more often in BIM project contexts, employees receiving this incomplete information tended to change their communication pattern to be formal in email. This meant they documented correspondence by cc'ing new partners (i.e leader/manager) in the communication process.

Conversely, employees who were located at the same physical location tended to manage this lack of information informally by turning to speak to their colleagues directly about design issues. This finding is consistent with Eckert et al. (2005) and Penn (1999), who found that office layouts in which communicators are located in the same area along with their manager and facilities such as a plotter and meeting room facilitated FTF interactions (Penn 1999) rather than the use of formal communication channels.

In sum, these various communication process patterns (i.e. formal and informal) manifested themselves at Mc1 through FTF contact or email. Here, the layout of the office environment,

the lack of skills and knowledge, the level of mutual trust, ineffective leadership, the presence of lower-skilled employees, and the lack on information provision all contributed to changes in the communication channels used at Mc1.

6.2.2.5 Leadership role: Lack of a reward structure

The research findings confirmed that Mc1 lacks a reward structure, not only in its collaborative BIM work environments, but also as a motivator for exchanging information, experience and knowledge. However, Watson-Manheim and Belanger (2002) found that reward structures that are clearly defined in an organisation were associated with increased knowledge and experience sharing among individuals. In addition, the authors found that rewarding individuals for sharing their knowledge with others resulted in changes in communication channel use, as they typically did not have sufficient time to familiarize themselves with how to use all available channels provided by an adopted technology. Although the professional context of this study was far less complex than the BIM work environment at Mc1, it would seem important to apply such a strategy in BIM contexts, as *"different information needs different sorts of channels to transmit"* (Eckert et al. 2005).

In addition, the findings showed that an absence of any reward structure at Mc1 might help to explain why some of its employees preferred to use more traditional communication channels (e.g. email or telephone calls), as they were not motivated to share their knowledge and experiences with others using the alternative communication channels that BIM provides. Homayouni et al. (2010: 781) stated that one BIM user noted that it is important to *"…work in a trust-built, incentive-based environment to produce collective values.''*

The view of organisational strategy in the literature (e.g. Homayouni et al. (2010), Watson-Manheim and Belanger (2002), and Ebrahim et al. (2009)) have shown that reward structures are considered one of the major responsibilities of leadership, and their application (or lack thereof) can reflect an organisation's culture in terms of supporting its employees and their performance. For example, some studies have linked rewards structures with effective team performance (e.g. Ebrahim et al. 2009) and the success of the communication processes (e.g. Eckert et al. 2005). In light of this, the absence of a reward structure at Mc1 might have contributed to employee unwillingness not only to share their experience and knowledge in general, but also to learn and share their knowledge on how to use new technology (i.e. BIM).

In sum, this discussion suggests that the role of leaders, a lack of mutual trust, technical difficulties and lack of information provision had the potential to change the type of communication channels used within this case study context. In addition, the absence of a reward structure at Mc1 might have decreased the willingness of employees share their knowledge and experience. However, the study results did not show any clear evidence of how this absence may have influenced the communication channels used within BIM work environments, despite the fact that it is a key factor in the literature (e.g. Watson-Manheim and Belanger 2002).

6.2.3 Theme 3: The impact of rumours

It is important to mention here that during the interview data collection period many rumours were circulating within the case study workplace. Subsequently, this environment may have contributed to faster dissemination of these rumours. In terms of understanding the potential effect of these rumours on communication channels, this question surprised the majority of the research participants as to how it might have related to the firm's BIM work environment. While some participants declined to answer questions about workplace rumours or denied their existence, these findings show that the term *'rumour'* was frequently mentioned by participants in their interviews and in informal settings with the researcher (e.g. lunch and coffee breaks). In this respect, another high-frequency term that contributed in part to the discovery of the rumours, was 'heard', as in *"I heard that.."* or *"they heard that…."* In addition, the research findings demonstrated that the external environment also contributed to the spread of rumours at Mc1 through different sources such as media (i.e. television) and non-employees (i.e. software vendors, experts and clients), and also influenced the communication patterns and channels at the firm. Furthermore, the results showed that respondents spoke of the effect of rumours on the firm in general, and within the BIM work environment in particular, in terms of three groups. These groups were classified into levels: 1) owner/top management team; 2) manager/leader; and 3) individuals, from which two sub-groups emerged: existing staff and new staff.

6.2.3.1 The impact of rumours at the owner/top management level

The study findings showed that rumours transmitted from the surrounding environment influenced the firm's work environment. This influence was due largely to what various media outlets reported with respect to issues that directly related to the stability of Mc1's staff, such

as the termination of contracts with (X) and reductions in the number of projects. The results showed that this led to changes in Mc1's communication patterns. For example, some team members communicated directly with top management (i.e. bottom-up communication), instead of communicating with their managers. This changed the communication process not only through the use of informal communication channels (i.e. telephone calls), but also because much of this communication transpired outside of work hours (i.e. at night). The presence of these rumours (i.e. unconfirmed information), and the use of informal communication channels rather than formal communication channels was found to be an inevitable consequence of verifying their content.

Another form of influence related to these rumours and the media's role in circulating them was rumours about the firm's 'members.' From general manager's standpoint, such rumours led some team members to ask to be excused from communicating with the person whom they believed generated these rumours. However, while the general manager eventually stated that these rumours were incorrect, they nonetheless impeded the firm's communication process by eliminating one of its components. Whether this component was the sender or the receiver, in the end, communication paths were closed, which subsequently affected the communication channels used at Mc1.

The respondents reported another impact of these rumours to be related to BIM's capabilities in improving design process performance. The firm's general manager (A2), offered some examples of these rumours, which dissuaded some team members in accepting the switch to BIM:

- *"The most widely circulated rumours that I heard from the staff concerned the belief that BIM would significantly reduce the employment percentage."*

- *"After the organisation implements BIM, the organisation will dismiss most of the staff, and only 10% to 15% of them will be required for conducting BIM-based projects."*

He went on to note that*, "…these rumours were behind the resistance of some to change to the BIM process."*

In light of this, the study results suggest that in some respects these rumours were either transmitted by or stemmed from sources such as software vendors and BIM seminars. As

stated above, the general manager highlighted the connection between rumours related to BIM features and the resistance of some employees toward BIM implementation.

6.2.3.2 The impact of rumours at the leader/manager level

The data analysis showed unexpected results regarding the spread of rumours at the leader/manager level. During their interviews, department managers consistently stated that no rumours existed in Mc1's workplace. In addition, the researcher observed that during these interviews, all of the managers declined to discuss the rumour issue, either by turning their heads or asking the researcher to move on to the next question. For example, one respondent stated, *"I'm not the right person to answer this question…. What is the next question?"* (A1, Design Manager). In fact, one manager stated that Mc1's workplace is *"a professional environment."* (A3, technical director, Mc1).

While this study does not focus on the content or sources of these rumours, this reluctance of managers to discuss them, even though their existence was confirmed by employees, seems to reflect how effectively they manage their work environments and build trust. However, it is worth mentioning that the managers may have denied the existence of these rumours because they refused to associate them with the performance of their team members and departments. And despite their denial of internal rumours, those same managers did acknowledge the presence and influence of rumours when they related to the external environment. For example, when asked if they have "*heard about any rumours within the organisation, particularly with respect to the global economic crisis?",* some respondents answered differently. For example, one respondent reported, *"Yes, I received a phone call from our colleagues at the (X) branch enquiring about a certain incident that occurred at our main branch."* (A4, Quality Control Manager). In this case, the nature of the rumours shifted from the performance of (X) person or (X) department at Mc1 to a global issue (i.e. the economic crisis). This again highlights the influence of rumours within the BIM environment, despite the attempts of managers to downplay them.

Regardless whether these managers denied these rumours or not, the findings show that rumours at Mc1 did circulate and were not limited to this branch, but rather they exceeded the boundaries of the workplace, and the reaction to them led employees who work remotely to inquire about their validity. As a result, these rumours, their transmission, and the inquiries about them had an impact on the formal and informal communication patterns at Mc1 and

subsequently on the types of communication channels used. For example, these rumours increased the demand for communication in general and increasing the use of informal communication channels, as opposed to following the formal protocols.

6.2.3.3 The impact of rumours at the individual level

Despite the diversity of the research participants in terms of skills, knowledge, and professions (i.e. engineers, architects, etc.), the data analysis showed that the majority of them agreed that rumours affected the way they communicate. In addition, despite the significant influence of these rumours, the study findings were clear that this influence differed slightly between existing and new staff members.

With respect to new staff at Mc1, the results revealed that, *"…from day one, new staff will begin hearing from others about the organisation's statement, staff attitudes, and recent conflicts…."* (A6, BIM coordinator). Many respondents maintained that this also contributes to way in which they communicate. Also, it appeared that workplace rumours dissuaded staff from using the informal communication channels, such as FTF communication, in order to avoid conflict. In addition, it seems that the presence of these rumours led some staff members to substitute informal communication methods for formal means, such as *''submission through the secretary.''* (A5, BIM Manager). In sum, new employees communicated with others, based on what they heard from the existing staff.

Existing staff members reacted differently to these rumours, which affected the implications on the communication channels used. Importantly, at the individual level, the results show that the types of rumours present at Mc1 typically related to: 1) administrative matters and the decisions made; 2) the performance of (X) professional and (X) department; and 3) the benefits and challenges of using BIM in practice. Based on the research findings, these rumours played a role in changing the communication process at Mc1 in a direct and informal manner. According to the respondents, this was an inevitable consequence due to the need to gossip and talk with their peers. This illustrates the connection between workplace rumours and employee decisions to spontaneously changes the communication channels they use. In addition, the results showed that communication processes increased as a result.

However, in addition to the types of rumours discussed above that circulated among employees within the BIM work environment, other rumours emerged during the BIM implementation process, including *"the implications of BIM technology for their [the*

employees'] future careers." For example, one respondent told his colleagues that, *''Whoever will not work with BIM will be out of the market soon.''* (A6, BIM coordinator) This statement suggests that a fear of losing one's position at Mc1 was driven in part by the BIM experts. It is important to mention that in general, the data analysis process for the rumour factor (see Chapter 5) explored some sources of these rumours. These sources were largely external, such as software vendors, seminars and clients, and others were internal. In addition, some respondents identified another internal source of rumours, which passed them along from outside sources: experts/BIM specialists such as the BIM coordinator and the BIM manager.

In sum, the findings revealed three distinct levels of influence in terms of rumours within the BIM work environment, as well as several primary types of rumours and their sources. The results also showed that the rumours surrounding the performance of (X) person or (X) department increased the gap between professionals within or across departments, and subsequently affected the use of formal channels for documentation purposes, for the simple reason to *"be safe and preserve my rights."* (A9, Design Architect). In addition, the research findings showed that the use of formal communication channels, such as email, replaced the informal means (e.g. FTF conversations and walk throughs). The results also made clear that the presence of rumours and their effect in the change to formal communication channels, is reflected in the workplace being characterised by the lack of mutual trust.

6.2.4 Theme 4: Communication protocols

In terms of communication processes at Mc1, communication protocols played a fundamental role in defining the channels used in the BIM work environment. The research findings revealed two types of protocols: 1) internal protocols that are influenced by organisational culture; and 2) external protocols that are typically stipulated in contractual documents and partnership agreement. The following section discusses both of these protocol types.

6.2.4.1 Internal communication protocols: The role and impact of organisational culture

Organisational culture emerged as one influential factor in changing the mechanism used for communication channels within the BIM work environment at Mc1. This section discusses this culture by focusing on the rules and regulations applied to Mc1's communication processes

within and across organisational boundaries. In this regard, the research findings revealed that several factors reflected the culture of the organisation, and that those factors contributed to changing the communication channels used at Mc1. The data analysis showed that the workplace environment for this case study could be characterised by several factors in terms of communication protocols that reflected Mc1's culture: 1) absence and ambiguity in identifying these protocols for team members; 2) the role of professional experience in selecting communication channels; 3) the documentation process as a procedural process; 4) the selection of communication channels based on employee needs; and 5) leadership authority in identifying custom approaches to communication protocols.

The data analysis suggests that the absence or ambiguity of communication protocols at Mc1 contributed not only in changing the communication channels used, but also in generating conflict among team members. For example, one respondent referred to the incorrect use of the cc protocol in email use, and while this is a common procedure, the incorrect listing of relevant recipients according to their position in Mc1's hierarchy resulted in conflicts. In addition, one respondent referred to his experience at another organisation, and the role organisational culture played there in clarifying this procedure in detail. In addition, the incorrect application of this practice not only generated conflict, but also resulted in "incorrect use" of the email protocol that led to an increase the number of the emails each recipient received. This finding of incorrect use of the email protocols is consistent with Watson-Manheim and Belanger (2002), who explored overloads in communication and information; every day each employee was receiving between 50 and 150 emails.

While the documentation process is a key procedural element for any organisation, the findings revealed that at Mc1 documentation normally occurs via email as final step in a series of stages. For example, the first stage is FTF conversation, the second is oral agreement on solutions, and finally these solutions are documented via official channels such as email. This finding is consistent with Watson-Manheim and Belanger (2002: 8), who noted that*, "…it's culture based. Our culture is email. If you talk to me on the phone… after you tell me something, I'll say, 'Great! Can you send that to me in an email?'".* The results of this study showed that BIM users at Mc1 use a similar protocol.

Furthermore, these findings track those of Dossick and Neff (2011:88), who investigated the importance of documenting oral communication within BIM environments. For example, one of their respondents stated, *"…if it isn't [in] an email, it's not real. If you have a face-to-face conversation, you need to document it in an email, or we have to follow it up in some kind of*

communication, but we can't rely upon verbal communication anymore." In addition, despite the availability of facilities at Mc1 (e.g. allocated meeting rooms for each department and telephone and chat systems), the interview responses suggest that the firm does not provide any instruction about when these channels should be used. In some respects, the results showed that selection of communication channels at Mc1 is based on employee needs. And while the organisation's role in clarifying communication protocols for their employees seems absent, the findings also suggested that employees learn how to use these through experience. To illustrate this point, the data analysis revealed that professional experience has played a fundamental role in determining how to communicate with others. As one respondent stated, *"…experience is the best teacher.''* (A7, Senior Architect, C1)

The findings also revealed that managers and leaders at Mc1 play an additional role in identifying who communicates, to whom, and how (i.e. which communication channels to use) both within and across different departments (see Section 6.2.2). This role and the authority that Mc1 gives its managers and leaders in this regard contributed to some extent to changes in the firm's communication channel use. This, in turn, led to differences in the types of communication channels used from context to context (i.e. from one department to another). Furthermore, the absence of internal protocols not only caused conflicts but could also have intensified the effects of the rumours.

In sum, it seems that the role organisational culture played at Mc1 in terms of not fully explaining its internal communication protocols had a significant effect on employee selection of which communication channels to use. In addition, this phenomenon impeded the way some employees communicated with their peers, which partially contributed to conflicts within the organisation. Finally, the study results did not give any indication as to what extent team size might play a role in influencing communication channel type.

6.2.4.2 External communication protocols: Contractual project requirements and partnership agreements

Along with the communication protocols that were influenced by Mc1's organisational culture, the results showed that the firm used another communication protocol for external and internal communication purposes. The findings revealed that this communication protocol differed from context to context based on various factors, such as: a) project dynamics (e.g. project needs, type and scale, and level of detail required); b) the type of

client; c) the type of partner; and d) partnership agreements, all of which are typically stipulated in the firm's contracts. In light of this, differences in these contracts resulted in variations in the types of communication channels used at Mc1. With respect to project dynamics, the usage rate of communication channels also varied according to project needs, type, and size.

The findings showed that the types of communication channels used at Mc1 are normally stipulated in the project contract, and the most common type of communication channel that is required is FTF meetings. This result is consistent with Emmitt and Gorse (2003), who found that the identification of formal communication channels and the frequency of meetings was associated with the contractual requirements for each project. For this study, the results showed that at Mc1 the partner and client type play a further role in determining the frequency of meetings as well as additional communication channels. These findings support those of Dainty et al. (2006) in arguing that the need to expand communication across organisational boundaries is an inevitable consequence of increased project scale and partnerships that require effective communication channels. In addition, the findings indicated that the range of project management applications is typically based on project type or firm needs, which results in variations in communication channels used from context to context.

In general, organizational culture played a role at Mc1 in terms of failing to fully explain its communication protocols and permitting its managers to determine their own protocols. In addition, professional experience also contributed to changes in communication channels used across contexts, from internal communication protocols to those stipulated in contracts. Together, these factors also resulted in changes in the communication channels used at Mc1.

In sum, this section discussed the factors that influenced changes in the communication channels used at Mc1 from the perspective of the firm's organisational culture. The following section presents the final theme that emerged from the data analysis, namely how the technical characteristics of BIM contributed to changes in Mc1's existing communication channels.

6.3 Group 2, Theme 5: The technical characteristics of BIM technology

Many studies have reported that BIM technology can play a positive role in improving communication during the design process (Ghaffarianhoseini et al. 2016; Li et al. 2014; Rowlinson et al. 2010; Sebastian 2011; Dossick and Neff 2011; Yalcinkaya and Singh 2015; Son et al. 2015; Barlish and Sullivan 2012), while the current study did not seek to address these benefits of BIM in particular, it did investigate if and how adopting BIM affected the current communication channels used at MC1. In the light of this, the findings showed that various forms of communication processes emerged in terms of BIM implementation, including: 1) communication across various software applications (i.e. interoperability); 2) visual communication (i.e. visualisation); 3) the ease of communication access (i.e. accessibility); and 4) Instant and concurrent communication (i.e. synchronisation). The following subsections will discuss these emergent forms of communication along with another BIM feature, clash detection.

6.3.1 The technical characteristics of BIM technology: Interoperability

The study results suggest that the interoperability capacity of BIM has improved the communication processes among various professionals. This finding is consistent with the literature, which shows clear advantages of BIM in terms of communication performance (e.g. Rowlinson et al. 2010; Li et al. 2014; Ghaffarianhoseini et al. 2016; Ciribini et al. 2016; He et al. 2015; Yalcinkaya and Singh 2015; Bryde et al. 2013). For this study, many respondents reported that the ability of BIM to transfer design data across various software platforms facilitated the exchange of design information such as data (i.e. design specifications) or design representations. In addition, the results showed that the technical advantages of BIM in exchanging project data across different disciplines contributed in part to improving the thinking process for employees at Mc1. These improvements included a greater understanding of model components in 3D, along with the information that supported them, and access to information that was not limited to their discipline. This, in turn, facilitated the process of BIM users in visualizing the work of other users. This finding is consistent with studies such as Haron et al. (2009), who argued that BIM has fostered a new method of thinking, which has resulted in changing various processes when compared to using CAD. The study results also showed that these BIM features helped respondents to gain a better understanding of 3D model components and become more aware of potential clashes in

project data. In addition, using BIM added a number of technical capabilities to Mc1's practice, which contributed to changing their use of communication channels. These features: 3D visualisation, accessibility, synchronization, and clash detection are presented in the following subsection.

6.3.2 The technical characteristics of BIM technology: 3D Visualisation

Several studies have reported the positive impact 3D visualisation has had in facilitating coordination and communication processes among BIM users (e.g. Sebastian 2011; Dossick and Neff (2011). In light of this, the study findings demonstrated that compared with the firm's former CAD system, the ability of BIM technology to visualise design drawings in 3D contributed to reducing the use of *"unwanted communication channels"* at Mc1 (Department Manager), including physically leaving the workspace; attending FTF meetings (either one-to-one or group meetings); design worksheets; and exchanging emails and telephone calls. In other words, the findings indicated that 3D visualization has provided Mc1's design team with a better understanding of its design products and helped to reduce design errors as well. The respondents reported that such improvements were due to that the ability of employees to 'see' design models virtually and identify design clashes, both of which have reduced the amount of wasted time and effort. This findings are consistent with those of Haron et al. (2009) and Sebastian (2011). The study results showed that employees at Mc1 have gained greater background in understanding design issues, which one respondent stated thus: *"…what I have to explain becomes visualised; we can see and explain it in five minutes."* (Department Manager, MC1). This stands in contrast to Mc1's CAD process, in which employees would often leave their workspaces to attend design discussion meetings that could reach up to *"…two to three hours, just to explain [the issues]to the engineers."* In terms of reducing the time spent on communication with design parties, the study results confirmed those of Bian et al. (2013), who argued that, *"Exchange of visual information among designers and clients mitigates the time needed for communicating complex ideas."*

In light of this, it seems that no clear evidence exists to clarify if BIM does indeed reduce or increase the need for the verbal communication processes. However, it is evident that BIM technology has helped to reduce the time spent on communicating with design parties, in some *"instances from 2-3 hours to 5 minutes*" (Department Manager). Furthermore, the study data suggests that the ability of BIM users at Mc1 to visualise their designs in 3D, increased understanding of projects for nonprofessionals, clients, and lower-skilled BIM users

at the firm. In addition, the results showed that implementing BIM resulted in faster decision-making processes and greater efficiency when compared to Mc1's CAD-based system. This finding supports those of Ghaffarianhoseini et al. (2016) and Sebastian (2011), in that the 3D visualization capabilities of BIM have supported design decisions both visually and more rapidly.

6.3.3 The technical characteristics of BIM technology: Accessibility

In addition, the access BIM users have to integrated models and design information have improved communication processes. The study results show that easy access to central design models across space and time has reduced the firm's need for FTF meetings, paper-based documents, and email. This result supports those of Dossick and Neff (2011). In addition, the results showed that Autodesk 360's cloud storage and file sharing capabilities also contributed to changing the communication channels at Mc1. With such features, design team members are able to review the Revit models from anywhere at any time, and share comments with the project team. However, it is worth mentioning that this application has been contractually refused by certain clients for use in their BIM projects due to security concerns related to project data. In addition, as this study investigated the effect of adopting BIM technology, particularly with respect to communication changes, it is consistent with Li et al. (2014), who reviewed 30 journal papers related to cloud-based BIM processes in order to investigate their benefits in practice. However, in terms of this study, the results did not reveal any indication of if and how this affected the communication channels used at Mc1.

6.3.4 The technical characteristics of BIM technology: Synchronization

The most frequent term respondents mentioned with respect to BIM features was *'synchronization.*' As a result, this study investigated the BIM synchronization process in terms of its potential effect on the communication channels used at Mc1. The data analysis indicated that the addition of real-time updates between integrated teams for recent design and construction plan amendments significantly reduced the number of design errors and requests for information. This finding supports those of Haron et al. (2009); Rowlinson et al. (2010); and Ghaffarianhoseini et al. (2016). This synchronization feature, along with the capability of 3D visualization, provided Mc1's integrated teams with a better perception and understanding of recent design changes without the need for verbal inquiries, or the use of other channels. In addition, the findings indicated that many communication process and

tasks that were formerly performed as FTF meeting (e.g. discussions around a table), have shifted to digital communication channels (i.e. through Revit models/servers).

6.3.5 The technical characteristics of BIM technology: Clash detection

Another important finding that emerged from the analysis concerns the clash detection feature of BIM technology, which played a role in changing the communication channels used at Mc1. The study findings indicated that the capability of BIM technology to instantly identify and visualise design clashes has facilitated a better understanding of design issues. As one respondent reported, *"…and this makes the decision-making process faster, more accurate and proper''* (A6, BIM coordinator). In addition, the results showed that the detection features embedded in Navisworks reduce the need for design coordination sessions, review meetings and one to one conversations. This finding is consistent with Ghaffarianhoseini et al. (2016), who reported that that the clash detection decreases the number of requests for information (RFIs). Furthermore, the clash detection feature has reduced the need for printing 2D drawings.

As a result, the reduced need for Face to Face meetings, emails, and 2D drawings has ushered in a new era of communication at Mc1. For example, the ability to exchange design data digitally and request further information through Revit has granted more users the ability to revise designs. Such new communication channels modes have changed the communication process at Mc1 from one that was verbal and co-located, to one that is digital, virtual and well-documented.

In this respect, when compared to CAD, BIM has reduced the time spent on FTF interaction at Mc1. However, implementing BIM has also increased/created the need for other types of communication, such as those conducted through the BIM system. Still, the study results showed that in addition to reducing the design conflicts, implementing BIM has reduced personal conflicts between design parties at Mc1. As one respondent stated, *"… whether [an issue] is my mistake, or someone else's… "* (A11, Design Architect), the issues are being visualized. This finding is consistent with Rowlinson et al. (2010: 573), who maintained that, *'…the key feature of BIM is that it does not lay blame.''* Additionally, the study results showed that employees at MC1 have become more aware of identifying potential clashes before they occur.

6.4 Summary

This chapter discussed the five major themes of this research with the aim to highlight the changes in the existing communication channels used within BIM work environment at Mc1, and why these changes occurred. It is worth noting that of these five themes, four relate to the conditions and characteristics of the organisation that adopted BIM technology. The first theme, resistance of team members towards changes, showed the continuity of using traditional channels and former tools, despite the availability of BIM's alternative channels. The second theme showed that the existence of rumours at Mc1 that circulated about (X) person and department and the perceived effectiveness of the new technology had a clear impact in changing the type and pattern of the communication channels used. The third theme, the role of the Mc1's leadership in selecting the team members and their corresponding capabilities with BIM, along with their role and in improving the trust level among these team members, together influenced the firm's communication channels. The fourth theme that related to organisational context, the communication protocols for internal or external use, also had a clear impact on changes. The fifth theme concerned the characteristics of BIM technology itself and the benefits this technology affords in improving the process of information exchange through access to integrated models, interoperability, 3D visualization, clash detection, and synchronisation. Based on the interview responses, these benefits contributed to reductions in dependence on previous channels, but did not completely eliminated their use. In addition, these benefits reduced the time spent on the communication process itself, as compared to the firm's former CAD structure. However, in discussing these responses, it is clear that no conclusive evidence emerged as to whether BIM technology influenced the need for verbal communication channels. The study conclusions and recommendations for future work are presented in Chapter 7.

Chapter 7

Conclusion

Chapter 7. Conclusion

7.1 Introduction

This chapter reviews the research aim and objectives presented in Chapter 1, summarises the research findings of this study, discusses the knowledge and methodological contributions that arose from the research results, and presents suggested directions for future study. The underlying aim of this research was to explore the implications of BIM implementation on existing mechanisms used for the communication channels in Saudi AE firms. To meet this aim, this thesis followed three sequential stages. The first was to review three sets of literature and theories: communication, team, and collaboration (see Chapter 2). The second was to run a pilot study (see Chapter 4) in order to refine the initial research questions that were shaped by the discussion of the potential factors extracted from various literatures and relevant theory (see Chapter 2). The final stage was to conduct case study research and analyse and discuss the empirical qualitative data collected in this study (see Chapters 5 and 6).

7.2 Summary of the research findings

Based on the research findings, it can be argued that implementing BIM played a significant role in the case study firm in improving communication process performance among its employees. This improvement was a function of the technical benefits that BIM added to the practice. For example, BIM has allowed professionals at the firm easy access to integrated project models not only from diverse workplaces but also from various applications, and has facilitated practices such as clash detection, 3D visualisation, and synchronizing design information (i.e. drawings and specifications) between project participants. Taken together, adopting BIM has not only reduced the time spent on communication at the firm but also dependence on more traditional communication channels, such as face to face meeting, email, and paper-based documents. This is because professionals are now able to see the building model virtually in 3D, understand relevant issues and prepare alternatives that can later be discussed as integrated teams, which has contributed to reducing the use of unnecessary communication channels.

However, the findings also suggest that it is difficult to conclude that adopting BIM has completely obviated particular communication channels, for two reasons. First, this study was not designed to compare the use of particular communication channels, but rather to explore changes in existing mechanisms used for communication channels as a whole and understand the reasons behind these changes. Second, and perhaps most important, the results showed that certain characteristics of the firm's organisational environment that incubated BIM played a fundamental role alongside the technology itself in changing the communication channels used. These characteristics include the presence of resistance by some professionals to adopting BIM and new communication channels; ambiguity in establishing internal communication protocols for professionals; the role of leadership in terms of building trust and selecting qualified employees; and the significant role rumours played increasing resistance among BIM users at the firm. Together, these factors changed the mechanism used for communication channels by increasing the need for the communication processes via different channels to document transmitted information, adding new lines of communication to protect employees their rights, or discarding established lines of communication due to rumours. Given this, one could conclude that changes occurred in the communication channels used when BIM was adopted, and that this was due to the technical features of this technology. However, the magnitude of the impact of organisational environment on these changes was significant.

7.3 Research aim and objectives

The main aim of this research was to explore the implications of BIM execution on existing communication channels used in the design process by various AE professionals. As stated previously, this aim was fulfilled by addressing the questions of what happened to the existing mechanism used for communication channels within the case study work environment after BIM was adopted, and why. In brief, the study findings suggest that changes in communication channels were dynamic, and that changes in communication types and patterns were not static at either within one department or broader organisational level. In addition, the thematic analysis suggests that the causes of this phenomenon of changes could be categorised into five themes: 1) leadership; 2) the impact of rumours spread; 3) resistance to change 4) communication protocols; and 5) technical BIM features. As a result, this aim was addressed by achieving the three objectives listed below.

Objective one: Review the literature to identify a range of potential factors that might influence communication channels used within BIM-related work environments, and to develop an analytical framework to use in the empirical work.

Fulfilling this objective identified a range of potential factors that may influence communication channels. Chapter 2 reviewed three sets of literature: communication, collaboration and virtual team and relevant theories, including communication theory (from linear to interactive processes), team theory, and cross-profession collaboration theory. This review identified 38 influential factors (see Chapter 2, Table 2-3) that were selected based on their influence on potential changes in communication channels used among various professionals. In addition, three underlying themes emerged that might contribute to changes in communication channels within BIM-related work environments: 1) team member characteristics; 2) leadership; and 3) methodology of information exchange. The outcome of this process part enabled the researcher to 1) developed analytical framework; 2) identify potential study themes; and 3) understand the impact of each factor on the performance for communication, team and collaboration processes, and subsequently, how they might affect communication channels. This contributed to 4) shaping the research questions required to address the aim of this study.

Objective two: Conduct case study research to explore the effect of BIM implementation on communication channels and why these effects occur

Chapter 4 discussed the case study method of this research that enabled the researcher to address 'what' happened to the communication channels at the case study firm, and 'why.' The researcher conducted semi-structured interviews with 22 AE participants at a leading Saudi firm that uses BIM. It is important to mention that the interview questions that were developed for Objective 1 were empirically evaluated in the pilot study. Based on the pilot study results, the interview questions were further developed in order to achieve the research aim.

Another significant outcome of this research strategy was that it allowed the researcher to understand the practitioners' work environment and social context by meeting them in informal settings and observing the design of their workplace and the technologies they use. This, in turn, facilitated deeper interpretation of the research participants' responses and led to further exploration of the factors that may have contributed to changes in communication

channels. In addition, many important findings of the case study analysis involved understanding to what extent the spread of rumours among various professionals within the organisation influenced communication patterns, and subsequently communication channels. In addition, the researcher's engagement with the practitioners' social environment revealed additional influential factors and how they affected and sometimes combined with other factors in changing communication channels. For example, there was a connection between employee resistance to change and the presence of rumours and how these rumours were reflected in this resistance. Another example concerned the relationship between rumours and the denial of their existence by leaders and managers, even as 'rumour' was the most frequently mentioned term the researcher noted during informal employee settings.

Objective three: Analyse collected data by drawing on the analytical framework developed in Objective one to inform and explore influential factors and effects on communication channels.

The fulfilment of this objective is discussed in Chapter 5. For this research, because the form of the thematic analysis was data-driven, its emergent themes were primarily driven by the qualitative interview data analysis. Furthermore, the analytical framework developed for Objective one was used to inform and further explore any influential factors that might exist. As a result, based on the research findings five underlying themes were found to affect the mechanism used for communication channels at the case study firm. Four of these themes related to characteristics and the conditions of the organizational environment: resistance to change, leadership, communication protocols applied and the impact of rumours. However, the fifth theme concerned the technical characteristics of BIM. Here, there was an indication that the impact of organisational environment characteristics appeared to be more influential on communication channels than the BIM technology itself**.** With respect to the impact of rumours, the professional environment of the firm was influenced both within and across organisational boundaries.

7.4 Study contribution

This section discusses the contribution of this research in terms of knowledge and methodology. With respect to **contribution to knowledge**, one significant finding concerned that the spread of rumours can change the mechanism used for communication channels

within AC firm adopted BIM technology. However, while the study results suggest that rumours significantly affected the communication channels at the case study firm with respect to either communication patterns or communication channel type, studies in the BIM and communication literature have not yet to address this phenomenon, particularly with respect to how communication channels could change in firms that adopt BIM technology. For this study, the results showed that changes emerged with respect to communication patterns (i.e. formal to informal, vice versa) and channel type (e.g. email, in-person meetings, paper-based documents, etc.).

The findings also suggest that these phenomena (i.e. changes by rumours) arose because of two significant factors: either desire to verify the validity of given rumours, or unlike the first, the acceptance of these rumours, which affected the way that employees communicated with others. In both cases, these changes affected the communication process dynamic between professionals in various ways, particularly within work environments that had adopted BIM. For example, many changes involved adding, deleting, or changing some components/elements of the communication process for senders, receivers, or channel types themselves. For instance, employees tended to substitute Face-to-Face meetings for email system; to avoid the direct communication with certain colleagues, and in some occasions, used email for documenting communication. Here, changes occurred not only to channel types but also in communication patterns, often moving from informal to formal means using documentation channels such as email. Another example concerned eliminating communication with certain recipients due to rumours concerning them.

The case study results showed that the effect of rumours at the firm appeared at three distinct levels: owner/top management, manager/leader, and individual. While this study did not focus on the source of these rumours, the findings revealed a correlation between external environments and the presence of rumours within the firm. In addition, the results showed that information that was transmitted in external environments such as television and other media, software vendors, experts and clients played a significant role in both accepting and rejecting the adoption of BIM, which subsequently affected the firm's communication channels.

Another contribution to knowledge that the study results suggest is that relying solely on communication theories, as were used initially (in Chapter 2, Section 2.4.1.2), is not sufficient for understanding and subsequently interpreting communication channel changes thoroughly in complex environments (e.g. those that employ BIM). Therefore, for this study, the

employing of three bodies of communication theory (i.e. liner to interactive model), although they are relatively diverse, including teams and collaboration theories (in Chapter 2, section 2.4.2, and 2.4.3) have provided another dimension of insights for this study that has contributed to the potential of identifying influential factors that effect change, and interpreting how they contributed to change.

This was particularly evident given that this study employed theories from three literatures: communication, team, and collaboration. This investigation resulted in identifying 38 potential factors that may influence communication channels. However, while the majority of these factors have been discussed in the literature in terms of their influence on the performance of communication, team, and collaboration processes, little is known about these factors with respect to their influence on communication channels at firms that adopt BIM.

The BIM literature suggests a strong consideration of project team communication as a critical factor in BIM project success (e.g. Barlish and Sullivan 2012; Liu et al. 2016). Similarly, some studies have explored the effect of BIM technology on communication processes (e.g. Dossick and Neff 2011) and developing communication processes for using BIM by focusing on interoperability (Ciribini et al. 2016), cloud BIM systems (Li et al. 2014) synchronous collaboration using BIM models (Isikdag and Underwood 2010) and clash detection (Wang et al. 2016). Although Dossick and Neff (2011), who focused in the FTF group meetings, demonstrated that BIM has not replaced the need for verbal and other informal communication means, such as hand sketches, there is no indication about changes on other communication channels.

In light of this, it is important to mention the thematic analysis of the interview data, which used the analytical framework that comprised 38 factors discussed in Chapter 2, revealed five themes that effected changes in communication channels at the case study firm. In addition, the case study data analysis suggested additional factors concerning technical BIM features when BIM features were not initially included in the analytical framework of this study. Along with the effect of technical BIM features, the role of rumours was also apparent, which suggests that adopting a new technology and any ambiguity about its benefits could increase the impact of rumours and resistance to change by professionals.

This study was inspired by Watson-Manheim and Belanger (2002), which posed the question of why user choice of communication channels varies across IT companies. While this study

context is different and less complicated than the present BIM collaborative system under investigation, the current study is consistent with this previous one in its interpretation of impacts and changes and in the role some factors play, such as reward structures, resistance to change, organisational culture, lack of trust, and individual preference. However, this study revealed additional influential factors.

Concerning this study's **contribution to methodology**, three distinct sets of concepts—theoretical models of communication processes, team theory, and cross-profession collaboration theory were used to understand the dynamic communication processes among diverse professionals in general and within BIM collaborative environments in particular. In addition, this study reviewed three sets of literature: communication, team, and collaboration; to select 38 distinct factors in terms of their potential effect on changes in communication channels. Consequently, these factors were discussed according to their influence with respect to the aforementioned literatures and theories. This, in turn, led to their categorisation into three major themes. These themes were then used to develop an analytical framework to investigate the effect of adopting BIM on communication channels. In this respect, it is important to mention that within each theme, each factor was been discussed in terms of its influence with respect to those different sets of literature and theory. This process served to shape the research questions that were examined in the pilot study (see Chapter 4). In addition, it helped to refine the research questions posed in the case study research and identify appropriate data collection techniques and select the proper case. Finally, the categorisation of these factors facilitated the data analysis process (see Chapter 5). As a result, this framework could be used by future researchers as a guide to investigating potential changes on communication channels, particularly with respect to the BIM literature. Furthermore, identifying these factors was a fundamental step in identifying changes to communication channels when adopting any new technology. Given this, this study provided the first step in this direction.

7.5 Future work

This study addressed the key question of this research, "What happens to communication channels with BIM-enabled firms, and why?" by conducting an empirical case study on the effect of BIM technology in communication processes within AE firm, but in Saudi Arabia. For that reason, re-examining the analytical framework which consists 38 potential factors, along

with the research findings to explore the impact of BIM technology in communication channels either in another context or countries, is essential for the generalisation purpose.

Furthermore, studies could evaluate these findings in and apply this framework to other contexts (e.g. companies, universities, hospitals,..etc). Or, in other collaborative technologies to investigate if these other environments which are in real consider as social environment due to social interaction among employees; do they usually share the same themes, or not?

In addition, applying theories other than those employed in this study might help to investigate other influential factors or insights or to interpret communication channel changes and their effects. In addition, studies could apply the analytical framework and findings of this research to explore other changes in communication channels for new collaborative technologies that support collaborative work.

Finally, there is a pressing need for researchers, developers, and practitioners to conduct studies on rumours as a new research trend, particularly with respect to how rumours originate and circulate in AE firms and other contexts. This new trend could help achieve desired goals and optimize benefits from the efforts and money expended for either adopting new technology and or training employees; to increase organisational productivity.

References

Al-sudairi, A.A., 2008. ACTIVITY-BASED COSTING (ABC) ANALYSIS IN DESIGN PROCESSES. In *Design Management in the Architectural Engineering and Construction Sector*. Brazi: CIB Rotterdam, pp. 321–330.

Al-Kharashi, A. & Skitmore, M., 2009. Causes of delays in Saudi Arabian public sector construction projects. *Construction Management and Economics*, 27(1), pp.3–23.

Alaghbari, W. et al., 2007. The significant factors causing delay of building construction projects in Malaysia. *Engineering, Construction and Architectural Management*, 14(2), pp.192–206.

Ale Ebrahim, N., Ahmed, S. & Taha, Z., 2009. Virtual Teams: a Literature Review. *Austrialian Journal of Basic and Applied Sciences*, 3, pp.2653–2669.

Alnaser, A. & Harty, C., 2016. The Implications of BIM Use on Communication Channels in the Design Process. In *CIB World Building Congress*. 30th May - 3rd June 2016, Tampere, Finalnd, pp. 930–941.

Alshalhoob, S., 2012. *AN INVESTIGATION INTO THE POTENTIAL USE OF BUILDING INFORMATION MODELLING FOR HEALTHCARE CONSTRUCTION PROJECTS IN SAUDI ARABIA, Master Thesis*. Waterford Institute of Technology.

Alsuliman, J., Bowles, G. & Chen, Z., 2012. CURRENT PRACTICE OF VARIATION ORDER MANAGEMENT IN THE SAUDI CONSTRUCTION INDUSTRY. *ARCOM, AC, UK*, (September), pp.1003–1012.

Alzara, M. et al., 2016. Using PIPS to Minimize Causes of Delay in Saudi Arabian Construction Projects: University Case Study. In *Procedia Engineering*. pp. 932–939.

Amabile, T.M. et al., 2001. ACADEMIC-PRACTITIONER COLLABORATION IN MANAGEMENT RESEARCH : A CASE OF CROSS-PROFESSION COLLABORATION. *Academy of Management Journal*, 44(2), pp.418–431.

Arain, F.M., 2008. IT-based approach for effective management of project changes: A change management system (CMS). *Advanced Engineering Informatics*, 22, pp.457–472.

Arain, F.M. & Pheng, L.S., 2007. Modeling for management of variations in building projects. *Engineering, Construction and Architectural Management*, 14, pp.420–433.

Arain, F.M., Pheng, L.S. & Assaf, S.A., 2006. Contractors' Views of the Potential Causes of Inconsistencies between Design and Construction in Saudi Arabia. *Journal of Performance of Constructed Facilities*, 20, pp.74–83.

Aranda-Mena, G. et al., 2009. Building information modelling demystified: does it make business sense to adopt BIM? *International Journal of Managing Projects in Business*, 2(3), pp.419–434.

Arayici, Y. et al., 2011. BIM adoption and implementation for architectural practices. *Structural Survey*, 29(1), pp.7–25.

Assaf, S.A. et al., 2001. The management of construction company overhead costs.

International Journal of Project Management, 19, pp.295–303.

Assaf, S.A. & Al-Hejji, S., 2006. Causes of delay in large construction projects. *International Journal of Project Management*, 24, pp.349–357.

Azhar, S., Hein, M. & Sketo, B., 2007. Building Information Modeling (BIM): Benefits , Risks and Challenges. *JBIM Journal of Building Information Modeling*, N. B. S. N. a. t. N. I. o. B. S. (NIBS), ed.

Baik, A., 2017. From point cloud to Jeddah Heritage BIM Nasif Historical House – case study. *Digital Applications in Archaeology and Cultural Heritage*, (January 2016), pp.1–18.

Barlish, K. & Sullivan, K., 2012. How to measure the benefits of BIM — A case study approach. *Automation in Construction*, 24, pp.149–159.

Bian, F. et al., 2013. Geo-informatics in resource management and sustainable ecosystem. *GRMSE 2013, Wuhan, China, November 8-10, 2013, Proceedings*. Springer

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(1478–887), pp.77–101.

Brennen, S.D. et al., 2007. Teams, computer modeling, and design. *IEEE Transactions on Systems, Man, and Cybernetics Part A:Systems and Humans*, 37, pp.995–1004.

Brewer, G. & Gajendran, T., 2010. a Case Study of the Effects of Attitude , Behaviour , and Project Team Culture on Building Information. In Proceedings of CIB W78 2010: 27th International Conference on Applications of IT in the AEC Industry.

Bryde, D., Broquetas, M. & Volm, J.M., 2013. The project benefits of building information modelling (BIM). *International Journal of Project Management*, 31(7), pp.971–980.

Bryman, A., 2012. *Social Research Methods* 4th editio., New York,: Oxford University press Inc.

Bubshait, A.A. & Farooq, G., 1999. Team Building and Project Success. *Cost Engineering*, 41, pp.34–38.

Chiu, M.-L., 2002. An organizational view of design communication in design collaboration. *Design Studies*, 23(2), pp.187–210.

Ciribini, A.L.C., Mastrolembo Ventura, S. & Paneroni, M., 2016. Implementation of an interoperable process to optimise design and construction phases of a residential building: A BIM Pilot Project. *Automation in Construction*, 71, pp.62–73.

Coates, P. et al., 2010. The limitations of BIM in the architectural process. In Hong Kong, China: First International Conference on Sustainable Urbanization (ICSU 2010).

Cochrane, S., Brodie, L. & Pendlebury, G., 2008. Successful use of a wiki to facilitate virtual team work in a problem-based learning environment. In *19th Annual Conference of the Australasian Association for Engineering Education: To Industry and Beyond; Proceedings of the*. Institution of Engineers, Australia, p. 429.

Collins, H., 2010. *Creative Research: The Theory and Practice of Research for the Creative Industries*, Bloomsbury Publishing.

Cramton, C.D., 2001. The Mutual Knowledge Problem and Its Consequences for Dispersed

Collaboration. *Organization Science*, 12, pp.346–371.

Creswell, J.W., 2009. *Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.)* Third Edit., London, United Kingdom: SAGE Publications, Inc.

Croft, R.S., Communication Theory. Available at: https://www.scribd.com/document/88393577/Communication-Models.

Daim, T.U. et al., 2012. Exploring the communication breakdown in global virtual teams. *International Journal of Project Management*, 30(2), pp.199–212.

Dainty, A., Moore, D. & Murray, M., 2006. *Communication in construction: Theory and practice* First edit., London, United Kingdom: Taylor & Francis.

Dekker, D.M., Rutte, C.G. & Van den Berg, P.T., 2008. Cultural differences in the perception of critical interaction behaviors in global virtual teams. *International Journal of Intercultural Relations*, 32(5), pp.441-452

Dineen, B.R., 2005. Teamxchange: A Team Project Experience Involving Virtual Teams and Fluid Team Membership. *Journal of Management Education*, 29, pp.593–616.

Dossick, C.S. & Neff, G., 2011. Messy talk and clean technology: communication, problem-solving and collaboration using Building Information Modelling. *Engineering Project Organization Journal*, 1(2), pp.83–93.

Dossick, C.S. & Neff, G., 2010. Organizational Divisions in BIM-Enabled Commercial Construction. *Journal of Construction Engineering and Management*, 136, pp.459–467.

Du, J., Jing, S. & Liu, J., 2012. Creating shared design thinking process for collaborative design. *Journal of Network and Computer Applications*, 35, pp.111–120.

Eadie, R. et al., 2013. BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, 36, pp.145–151.

Eastman, C. et al., 2008. BIM Tools and Parametric Modeling. In *BIM Handbook : A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. Hobken, New Jersy: John Wiley & Sons, Inc.

Eckert, C., Clarkson, J. & Stacey, M., 2001. INFORMATION FLOW IN ENGINEERING COMPANIES : PROBLEMS AND THEIR CAUSES. In *International Conference on Engineering Design*. Glasgow, UK: Process and Information Issues (ICED'01), pp. 43–50.

Eckert, C., Maier, A. & McMahon, C., 2005. Communication in design. In J. Clarkson & C. Eckert, eds. *Design Process Improvement: A review of current practice*. Cambridge, UK: Springer, pp. 232–261.

Ely, M. et al., 2005. *On writing qualitative research: Living by words*, The Falmer Press, London and Bristol.

Emmitt, S. & Gorse, C., 2007. *Communication in construction teams*, USA and Canada: Taylor & Francis.

Emmitt, S. & Gorse, C.A., 2003. *Construction communication* First edit., Oxford, UK: Blackwell Puplishing Inc.

Emmitt, S. & Gorse, C.A., 2009. *Construction Communication*, John Wiley & Sons.

Falqi, I., 2004. *Delays in project completion: A comparative study on construction delay factors in Saudi Arabia and the United Kingdom, Master Thesis*. Heriot Watt University.

Fisher, M., and Fisher, M.D., 1998. *The Distributed Mind, New York: American Management Association., 1998.*, New York,: American Management Association.

Fjermestad, J. & Ocker, R.J., 2007. Communication and leadership differences in virtual design teams: Why some teams do better than others. *Journal of the Brazilian Computer Society*, 13(3), pp.37–50.

Gabriel, G.C. & Maher, M. Lou, 2002. Coding and modelling communication in architectural collaborative design. In *Automation in Construction*. pp. 199–211.

Geber, B., 1995. Virtual teams. *Training*, 32(4), pp.36–40.

Ghaffarianhoseini, A. et al., 2016. Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews*, (September), pp.1046-1053

Goes, R.H.T.B. & Santos, E.T., 2011. DESIGN COORDINATION WITH BUILDING INFORMATION MODELING : A CASE STUDY. In *Proceedings of the CIB W78-W102 2011: International Conference –Sophia Antipolis, France, 26-28 October*.

Goffman, E., 1959. *The presentation of self in everyday life*, Edinburgh: Doubleday.

Haron, A., Marshall-Ponting, A. & Aouad, G., 2009. Building information modelling in integrated practice. In *2nd Construction Industry Research Achievement International Conference (CIRIAC 2009)*. Kuala Lumpur, Malaysia.

Harty, C., 2008. Implementing innovation in construction: contexts, relative boundedness and actor-network theory. *Construction Management and Economics*, 26(10), pp.1029–1041.

Hatem, W.A., Kwan, A. & Miles, J., 2012. Comparing the effectiveness of face to face and computer mediated collaboration. *Advanced Engineering Informatics*, 26(2), pp.383–395.

He, Q. et al., 2015. Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis. *International Journal of Project Management*, *4*(35), pp.670-685.

Hertel, G., Geister, S. & Konradt, U., 2005. Managing virtual teams: A review of current empirical research. *Human Resource Management Review*, 15, pp.69–95.

Homayouni, H., Neff, G. & Dossick, C.S., 2010. Theoretical Categories of Successful Collaboration and BIM Implementation within the AEC Industry. In *Construction Research Congress*. ASCE, pp. 778–788.

Hooper, M. & Ekholm, A., 2010. A pilot study: Towards BIM integration - An analysis of design information exchange & coordination. *CIB W78: 27th International Conference*, pp.16–18.

Hulnick, G., 2000. “Doing Business Virtually.” *Communication World*, 17(3), pp.33–36.

IEEE, 1990. IEEE Standard Computer Dictionary. A Compilation of IEEE Standard Computer Glossaries. In *Institute of Electrical and Electronics Enginerrs*. New York.

Isikdag, U. & Underwood, J., 2010. Two design patterns for facilitating Building Information

Model-based synchronous collaboration. *Automation in Construction*, 19(5), pp.544–553.

Jarvenpaa, S.L. & Leidner, D.E., 1999. Communication and Trust in Global Virtual Teams. *Organization Science*, 10, pp.791–815.

Jassawalla, A.R. & Sashittal, H.C., 1998. An Examination of Collaboration in High-Technology New Product Development Processes. *Journal of Product Innovation Management*, 15(3), pp.237–254.

Kivimäki, M. et al., 2000. Communication as a determinant of organizational innovation. *R&D Management*, 30(1), pp.33–42.

Li, H., Wong, J. & Li, H., 2014. A REVIEW OF CLOUD-BASED BIM TECHNOLOGY IN THE CONSTRUCTION SECTOR. *Journal of Information Technology in Construction*, 19(August), pp.281–291.

Linderoth, H.C.J., 2010. Understanding adoption and use of BIM as the creation of actor networks. *Automation in Construction*, 19(1), pp.66–72.

Lipnack, J. & Stamps, J., 1997. *Virtual teams: Reaching across space, time, and organizations with technology*, New York, NY, USA: John Wiley & Sons, Inc.

Liu, Y., Nederveen, S. Van & Hertogh, M., 2016. Understanding effects of BIM on collaborative design and construction: An empirical study in China. *JPMA*. International Journal of Project Management, pp. 686-698.

Lu, W., Zhang, D. & Rowlinson, S., 2013. BIM COLLABORATION : A CONCEPTUAL MODEL AND ITS CHARACTERISTICS. , (September), pp.25–34.

Maccoby, M., 2000. Understanding the Difference Between Management and Leadership. *Research Technology Management*, 43(1), pp.43–57.

Mahamid, I., 2016. Micro and macro level of dispute causes in residential building projects: Studies of Saudi Arabia. *Journal of King Saud University - Engineering Sciences*, 28(1), pp.12–20.

Maier, A.M. et al., 2009. Reflecting communication: a key factor for successful collaboration between embodiment design and simulation. *Journal of Engineering Design*, 20(3), pp.265–287.

Maier, a. M. et al., 2008. Exploration of Correlations between Factors Influencing Communication in Complex Product Development. *Concurrent Engineering*, 16(1), pp.37–59.

Mark, G., 2001. Meeting Current Challenges for Virtually Collocated Teams: Participation, Culture and Integration. In L. Chidambaram, & I. Zigurs (Eds.). Our Virtual World: The Transformation of Work, Play and Life via Technology. Hershey: IGI Global, pp. 74–93.

Marzouk, M., Abdelkader, E.M. & Al-Gahtani, K., 2017. Building information modeling-based model for calculating direct and indirect emissions in construction projects. *Journal of Cleaner Production*, 152, pp.351–363.

McGrath, J.E., 1984. *Groups: Interaction and performance*, New Jersey: Prentice-Hall Englewood Cliffs.

McGraw-Hill, C., 2008. Building Information Modeling Trends. *SmartMarket Report*.

McQuail, D., 1994. *Mass Communication Theory* 2nd ed., London, United Kingdom: SAGE Inc.

Mintzberg, H., 1973. *The Nature of Managerial Work*, New York,: Harper & Row.

Mohaimeed, E., 2009. *Documenting the Architectural Design Process in Saudi Arabia, Identifying and Classifying the Barriers, and Improving the Design Process Through Object-Oriented Simulation, Master Thesis*. Dammam University.

Morris, T. & Wood, S., 1991. Testing the survey method: Continuity and change in British industrial relations. *Work Employment and Society*, 5, pp.259–282.

National Commercial Bank (NCB), 2010. *Report in Saudi Construction Sector*.

Nour, M., 2012. BIM support for design change management and workflow approval. In *ISCCBE*. Moscow, Russia: 14th International Conference on Computing in Civil and Building Engineering.

Ocker, R.J. & Fjermestad, J., 2008. Communication Differences in Virtual Design Teams : Findings from a Multi-Method Analysis of High and Low Performing Experimental Teams. *ACM SIGMIS Database*, 39, pp.51–67.

Otter, A.F. den & Prins, M., 2002. Architectural design management within the digital design team. *Engineering, Construction and Architectural Management*, 9, pp.162–173.

Paré, G. & Dubé, L., 1999. VIRTUAL TEAMS : AN EXPLORATORY STUDY OF KEY CHALLENGES AND STRATEGIES Guy Paré. In *Proceedings of the 20th international conference on Information Systems*. Association for Information Systems, pp. 479–483.

Penn, A; Desyllas, J; Vaughan, L., 1999. space of innovation: Interaction and communication in the work environment. *Environment and Planning B: Planning and Design*, p.26 (2) pp. 193–218.

Penttilä, H., 2006. Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. *Electronic Journal of Information Technology in Construction*, 11, pp.395–408.

Powell, A., Piccoli, G. & Ives, B., 2004. Virtual Teams : A Review of Current Literature and Directions for Future. *Data Base For Advances In Information Systems*, 35, pp.6–36.

Rahim, M.A., 2002. TOWARD A THEORY OF MANAGING ORGANIZATIONAL CONFLICT. *International Journal of Conflict Management*, 13(3), pp.206–235.

Robson, C., 2002. *Real World Research: a Resource for Social Scientists and Practitioner-Researchers* 2nd ed., Oxford, UK: Blackwell Puplishing Inc.

Rogers, E.M. & Kincaid, D.L., 1981. *Communication Networks: Toward a New Paradigm for Research*, New York, Free Press.

Rowlinson, S. et al., 2010. Implementation of Building Information Modeling (BIM) in construction: A comparative case study. *AIP Conference Proceedings*, 1233(PART 1), pp.572–577.

Sackey, E., Tuuli, M. & Dainty, A., 2014. Sociotechnical systems approach to BIM implementation in a multidisciplinary construction context. *Journal of Management in Engineering*, 31(1), A4014005

Saunders, M., Lewis, P. & Thornhill, A., 2009. Research Methods for Business Students. Financial Times.

Schramm, W., 1997. How communication works. *Mass media & society*, pp.51–66.

Sclater, N., Grierson, H., Ion, W.J. & MacGregor, S.P., 2001. Online collaborative design projects: overcoming barriers to communication. *International Journal of Engineering Education*, 17, pp.189–196.

Sebastian, R., 2011. Changing roles of the clients, architects and contractors through BIM. *Engineering, Construction and Architectural Management*, 18(2), pp.176–187.

Senescu, R.R. & Haymaker, J.R., 2013. Evaluating and improving the effectiveness and efficiency of design process communication. *Advanced Engineering Informatics*, 27(2), pp.299–313.

Shachaf, P., 2005. Bridging cultural diversity through e-mail. *Journal of Global Information Technology Management*, 8, pp.46–60.

Shannon, C.E. & Weaver, W., 1949. *The Mathematical Theory of Communication*, Urbana, Illinois: University of Illinois Press.

Sidawi, B. & Al-Sudairi, A.A., 2014. The use of advanced computer based management systems by large Saudi companies for managing remote construction projects. In *Procedia Engineering*. pp. 161–169.

Sidawi, B. & Omairi, S. Al, 2010. AN EXPLORATION OF THE POTENTIAL USE OF A WEB-BASED PROJECT MANAGEMENT SYSTEM TO MANAGE CONSTRUCTION. , 15(67), pp.67–74.

Sidawi, B., Sidawi, B. & Arabia, S., 2012. MANAGEMENT PROBLEMS OF REMOTE CONSTRUCTION PROJECTS AND POTENTIAL IT SOLUTIONS : THE CASE OF KINGDOM OF SAUDI ARABIA. *Journal of Information Technology in Construction -*, 17(ISSN 1874-4753), pp.103–120.

Simonin, B.L., 1997. The importance of collaborative know-how: An empirical test of the learning organization. *Academy of Management Journal*, 40(5), pp.1150–1174.

Al Soliman, K., 2012. *The Evaluation of the challenges and benefits of implementing BIM in the Kingdom of Saudi Arabia, Master Thesis*. University of Wolverhampton.

Son, H., Lee, S. & Kim, C., 2015. What drives the adoption of building information modeling in design organizations ? An empirical investigation of the antecedents affecting architects behavioral intentions. *Automation in Construction*, 49, pp.92–99.

Spaho, K., 2013. Organizational Communication and Conflict Management. *Management: Journal of Contemporary Management Issues*, 18(1), pp.103–118.

Sproull, L., Kiesler, S. & Kiesler, S.B., 1992. *Connections: New ways of working in the networked organization*, MIT press.

Succar, B., 2009. Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, 18(3), pp.357–375.

Succar, B. et al., 2014. The Five Components of BIM Performance Measurement. *Building Design*, 19(September), pp.287–300.

Sultan, F., 2009. *[Re-engineering of work systems (Reengineering)]* 2th edition., Riyadh, King Saudi Arabia: king Fahd National Library.

Torrington, D. & Hall, S., 1998. *Human resource management and the personnel function*, London: Routledge.

Tucker, R. & Abbasi, N., 2012. Conceptualizing teamwork and group-work in architecture and related design disciplines. In *46th Annual Conference of the Architectural Science Association*. Gold Coast: Deakin Research Online, pp. 1–8.

Volk, R., Stengel, J. & Schultmann, F., 2014. Building Information Modeling (BIM) for existing buildings — Literature review and future needs. *Automation in Construction*, 38(0), pp.109–127.

Wang, L. et al., 2016. Process Knowledge Capture in BIM-Based Mechanical , Electrical , and Plumbing Design Coordination Meetings. , 30(2), 04015017

Wang, L.H. et al., 2002. Collaborative conceptual design - state of the art and future trends. *COMPUTERAIDED DESIGN*, 34, pp.981–996.

Watson-Manheim, M.B. & Belanger, F., 2002. Exploring communication-based work processes in virtual work environments. In *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*. IEEE Comput. Soc, pp. 3604–3613.

Xue, X. et al., 2012. IT supported collaborative work in A/E/C projects: A ten-year review. *Automation in Construction*, 21, pp.1–9.

Yalcinkaya, M. & Singh, V., 2015. Patterns and trends in Building Information Modeling (BIM) research: A Latent Semantic Analysis. *Automation in Construction*, 59, pp.68–80.

Yan, H. & Damian, P., 2008. Benefits and Barriers of Building Information Modelling. In *12th International Conference on Computing in Civil and Building Engineering 2008.*

Yin, R.K., 2009. *Case Study Research: Design and Methods* Fourth Edi., London, United Kingdom: SAGE Inc.

Appendixes

List of Appendixes:

Appendix 1: Pilot Study Questionnaire Questions

University of Reading

Study Title: BIM, and Communication Channels
Researcher: Aljwhara A.Alnaser Email: A.A.A.Alnaser@pgr.reading.ac.uk.
Programme of study: Ph.D. School of Construction Management and Engineering
Faculty/University: University of Reading
Project Supervisor: Dr. Chris Harty

This survey is part of a study on 'BIM, and Communication channels' which is being conducted by Aljwhara A.Alnaser, a Ph.D. student in the School of Construction Management and Engineering at the University of Reading.

As an employee in a building surveyors firms, you are invited to participate in this study. Could you please complete this form and return it by email to the following address by / /2015; to A.A.A.Alnaser@pgr.reading.ac.uk. Participation is voluntary; you do not have to complete all of the questions, and you can stop at any time. Responses are **confidential.** The only persons to see the questionnaire will be myself and my supervisor.

Your identity and place of employment will not be mentioned within any publications/presentations resulting from this survey. **By completing and returning this questionnaire, you understand that you are giving consent for your responses to be used for the purposes of this research project.** If you have any questions or concerns about this research, please contact Researcher: Aljwhara Alnaser at A.A.A.Alnaser@pgr.reading.ac.uk.

- **Participant Name:**.....
- **Name of company:**.....
- **Contact number or email (if appropriate):**.....

List of questioner Questions For BIM-user: Such questioner consists two sections.

Section one: Questioners questions (بعض الاسئلة قد تحتمل اكثر من اجابة)

1. **What is the nature of your present job? ما هي طبيعة عملك الحالي**

- Architect
- Designer
- Drafter
- Project manager
- If other, please specify.....

2. **How long have you been engaged here? عدد سنوات عملك في المؤسسة**
- 1 year.
- 2 years.
- 3 years.
- 4+ years.

3. **How long has BIM been implemented within your firm? منذ متى تم تطبيق البيم في المؤسسة**
- 1 year.
- 2 years.
- 3 years.
- 4+ years.

4. **How many projects have you completed by using BIM? ما هي عدد المشاريع التي نفذت باستخدام البيم**
- 1-3
- 3-5
- 5-10
- 10+

5. **Do you apply BIM in certain phases, or for the whole design process? هل تم تطبيق البيم على مرحلة معينه أو على كامل مراحل العملية التصميمية ؟**
- Certain design phases, please specify.....
- The whole design process.

6. **Which BIM tools (software) do you use in your projects? ما هي أدوات البيم المستخدمه في تنفيذ المشاريع**
- Revit(arch, struct, MEP)
- BENTLEY (ARCH,STRUCT,MECH,ELECT)
- Autodesk Naviswork.

Appendix 1: Pilot Study Questionnaire Questions

- Vico.
- Graphisoft archicad
- Bentley generative components
- Nemetschek vectoworks. Gehry technologies digital project
- Tekla
- Beck technology Dprofiler
- Innoavaya
- Dassault systems CATIA
- Solibri Model checker
- Synchro project constructor.
- If other, please specify……..

7. What was the most important reason as to why your firm chose to adopt BIM? ما هو السبب وراء استخدام البيم في المؤسسة

- Effectively for exchanging and sharing information. لكفاءتها في نقل وتبادل المعلومات
- Design representations; visualization. لتمثيليات التصميمية (القدرة البصرية)
- Business value Improvements in cost/time/quality. تحسين اداء العمل في كل من الوقت والتكلفة والجودة
- Better collaboration between stakeholders.تحسين التعاون بين أصحاب المصلحة

8. How would you describe BIM? (check one or more) كيف يمكنك وصف البيم؟ اختار واحد او اكثر

- BIM is a part of the software. البيم مجرد برنامج.
- BIM is a technology..البيم عبارة عن تكنولوجيا
- BIM is a process..البيم عبارة عن عملية
- BIM is a information management. البيم اداره للمعلومات
- BIM is information exchange process. البيم عباره عمليه لتبادل المعلومات
- If other, please specify إذا أخرى، يرجى تحديد ……

9. What are the types of communication channels being used for exchanging and sharing information among professionals? (check one or more)
ما هي أنواع طرق الاتصال المستخدمة لتبادل وتقاسم المعلومات بين المهنيين؟ اختر واحدة أو أكثر.

- Telephone.الهاتف
- Emails.الايميلات
- Face to face meeting. المقابله وجهه لوجهه
- Video conference.
- If other, please specifyإذا أخرى، يرجى تحديد ……

10. How often do you use Telephone per day? كم عدد المرات التي كنت تستخدم الهاتف في اليوم الواحد

- 1-5
- 10-15
- 30-45
- 45-60

11. How often do you use email per day?كم عدد المرات التي كنت تستخدم البريد الإلكتروني في اليوم الواحد

- 1-5
- 10-15
- 30-45

45-60

12. How often do you use face to face meeting? كم عدد المرات التي كنت تستخدم الاجتماعات وجها لوجه

- Every week
- Every day
- Every other day
- Every month
- If other, please specify……

13. How often do you use Video conference?

- Every week
- Every day
- Every other day
- Every month

- If other, please specify……

14. What types of communication channels are used for exchanging BIM models, in particular? (Check one or more)
ما هي أنواع وسائل الاتصال المستخدمة في تبادل نماذج **BIM** ، على وجه الخصوص ؟ (اختر واحدا أو أكثر)

- By Emails.

- By BIM server.
- Cloud.
- By EDMS.
- By Extnanizt.
- If other, please specify……..

15. Section two: Please rate how strong, or weak are the following factors on the making changes on the existing mechanism used for communication channels?

القسم الثاني: يرجى تقييم مدى قوة أو ضعف العوامل التالية في إجراء تغييرات على آلية القائمة في استخدام وسائل الاتصال؟

	Factors	Extremely Strong 1	Strong 2	Neutral 3	Weak 4	Very Weak 5	N/A 6
1.	Do you think BIM helps to improve communication between project parties هل تعتقد BIM ساعد في تحسين التواصل بين الأطراف المشاركة في المشروع						
2.	Do you think BIM has facilitated exchanging and sharing data with all other professionals involved in a project? هل تعتقد BIM سهلت من عمليه تبادل وتقاسم البيانات مع الاعضاء المشاركين في المشروع؟						
3.	Do you think Diversity of communication channels that BIM provided, have contributed on making changes on old communication channels used. هل تعتقد أن تنوع وسائط الاتصال التي يوفرها البيم، ساهمت في إجراء تغييرات على قنوات الاتصال القديمة المستخدمه؟						
4.	Is face to face meeting still fundamental on BIM based project? هل مازال الاجتماع وجهه لوجه أساسيا في المشاريع المعتمده على **BIM** ؟						
5.	With BIM face to face meeting, is the hand sketches being used more than before? في الاجتماع وجهه لوجه في بيئه BIM ، هل اسكتشات اليد تستخدم أكثر من ذي قبل؟						
6.	To what extent organizational culture constitute a resistance to team members toward using a new communication channels. إلى أي مدى ثقافة المنظمة تشكل عائق لفريق العمل نحو استخدام قنوات اتصال جديدة.						
7.	Is there any role for factor 'Individual preference' on making change on communication channels. هل هناك أي دور لعامل "التفضيل الفردي" لبعض الاعضاء حول استخدام قناه اتصال معينة، في إجراء تغيير على قنوات الاتصال المستخدمة.						
8.	To what extent lack of trained staff impact on making change on communication channels used. ما مدى تأثير نقص وجود الموظفين مدربين في إجراء تغيير على قنوات الاتصال المستخدمة.						
9.	To what extent lack of handling technical conflicts (technical support) impact for making changes on communication channels used. إلى أي مدى النقص في معالجة الصراعات الفنية (الدعم الفني) اثر في إجراء تغييرات على قنوات الاتصال المستخدمة.						
10.	To what extent staff resisted to learn new technology impact on making changes on communication channels used. الى أي مدى اثر مقاومه الموظفين للتعلم تكنولوجيا جديدة احدث تغييرات على قنوات الاتصال المستخدمة.						
11.	To what extent the lack of training for using some of BIM communication channels might be constituted obstacle towards change to new channels. إلى أي مدى يشكل نقص التدريب على استخدام بعض قنوات الاتصال باستخدام BIM عائقا نحو التغيير إلى قنوات جديدة.						
12.	Do you think the ability of BIM for sharing and storing information, led to some changes on the old mechanisms of communication channels used before BIM entered? هل تعتقد أن قدرة BIM في تبادل وتخزين المعلومات، ادت إلى بعض التغييرات على الآليات القديمة المستخدمة في قنوات الاتصال قبل ادخال BIM ؟						
13.	Do you think that the role of institutional through motivate their team						

Appendix 1: Pilot Study Questionnaire Questions

	members play a key role on making some changes on mechanism used for communication channels? هل تعتقد ان دور المؤسسة الهندسيه من خلال تحفيز موظفيها لعب دور مهم في احداث تغير في الية قنوات الاتصال المستخدمة؟						
14.	Are the lack of shared common knowledge and skills between parties impacted on choosing the communication channels? هل نقص المعرفة والمهارات المشتركة بين الطرفين أثرت على اختيار قنوات الاتصال؟						
15.	Is the leader skill played key role on making change on communication channels used. هل مهارة القائد لعبت دورا اساسي في إجراء تغيير على قنوات الاتصال المستخدمة؟						
16.	To what extent might the insufficient of rewards structure be made some changes on mechanism used for communication channels. إلى أي مدى يشكل عدم كفاية نظام المكافآت في إجراء بعض التغييرات على آلية استخدام قنوات الاتصال؟						
17.	Does the potential changes on communication channels is due to the lack of leader monitoring, in terms of tracking the process of information exchange across certain channels rather than another, which in turn led team members to use alternatives channels ? هل التغيرات المحتملة على وسائط الاتصال بسبب عدم وجود مراقبة من قبل القائد، من حيث تتبع عملية تبادل المعلومات عبر وسائط معينة من دون الآخرى، الأمر الذي بدوره أدى أعضاء الفريق لاستخدام قنوات اتصالية بديله؟						
18.	To what extent deficiency of process of communication by the leader to their team members contributed to making changes on communication channels used. إلى أي مدى ضعف عملية التواصل من قبل القائد لأعضاء فريقه، ساهم في إجراء تغييرات على قنوات الاتصال المستخدمة.						
19.	Do you think the level of leader skills and experience play a critical role in making changes in communication channels used? هل تعتقد أن مستوى مهارات القائد والخبرة تلعب دورا حاسما في إحداث تغييرات في قنوات الاتصال المستخدمة؟						
20.	Is the availability about design information which provided by BIM technology, might be contributed to reducing the dependency degree on the email system, or face to face meeting? هل توافر معلومات عن التصميم الذي توفرها التكنولوجياBIM ، قد ساهمت في التقليل من درجة الاعتمادية على نظام البريد الإلكتروني أو الاجتماع وجها لوجه ؟						
21.	Do you think that overload information has played a role for making changes in the mechanism used for communication channels. هل تعتقد أن المعلومات الزائدة قد شكلت دورا مباشر في إجراء تغييرات علي آلية استخدام قنوات الاتصال.						
22.	Is there any role for unconfirmed rumor in relation to how some communication channels are effective to use than others. هل هناك أي دور للشائعات غير مؤكدة في ما يتعلق حول فعاليه بعض قنوات الاتصالات لاستخدام أكثر من غيرها؟						
23.	Are some professionals tend to use some communication channels rather than others, as the way to avoiding the technical problems? هل بعض المهنيين يميلون إلى استخدام بعض قنوات الاتصالات بدلا من غيرها، كوسيلة لتجنب المشاكل التقنية؟						
24.	Is the lack of real-time interpretation skill for various design representations by professionals, have contributed to keep using some old channels, despite their inability to convey information properly. هل النقص في مهارة التفسير اللحظي لمخرجات التصميمية المختلفة من قبل الممارسين، ساهمت في استمرارية استخدام بعض قنوات الاتصال القديمة، على الرغم من عدم قدرتهم على نقل المعلومات بشكل صحيح.						

- **If there any other comments:إذا كان هناك أي تعليقات أخرى**

Appendix 2: Pilot study Interview questions

Study Title: BIM, and Communication Channels
Researcher: Aljwhara A. Alnaser Email: A.A.A.Alnaser@pgr.reading.ac.uk.
Programme of study: Ph.D. School of Construction Management and Engineering
Faculty/University: University of Reading
Project Supervisor: Dr. Chris Harty

Participant Name:.....
Name of company:.....
Contact number or email (if appropriate):.....

List of Interview Questions For BIM-user

Theme1: Information exchange

1. Do you think BIM help to improve communication process between project parties, and how?
   - هل تعتقد أن BIM ساعد في تحسين عملية الاتصال بين الأطراف المشاركة في المشروع، وكيف؟
2. What challenges do you encounter when communicate by using BIM technology?
   - ما هي التحديات التي واجهتك عند ممارسه الاتصال بين اعضاء الفريق باستخدام تكنولوجيا البيم ؟
3. Do you think that the individual preference play a role in making some changes on communication channels? And how? (new added)
   - هل تعتقد ان التفضيل الفردي لعب دور في احداث تغيير على قنوات الاتصال وكيف؟
4. Based on your experience, what different types of communication channels are BIM provided, and what types of channels did designers use?
   - بناء على تجربتك، ما هي أنواع قنوات الاتصال المختلفة التى توفرها تكنولوجيا البيم، وما هي أنواع القنوات التي تم استخدامها اثناء تصميم المشاريع ؟
5. Is there any role for unconfirmed rumor regarding, for example, the effectiveness of some channels rather than others, cause some changes on communication channels used?
   - هل هناك دور للإشاعة غير المؤكده فيما يتعلق على سبيل المثال: حول فعاليتها شكلت تغيرعلى قنوات الاتصال المستخدمة؟
6. Consequences of insufficient information provision
   i. What are the consequences of insufficient information provision about joint work on the mechanism used for communication channels between professionals?
   - ما هي الاثار المترتبة من عدم كفاية المعلومات المتوفرة حول العمل المشترك على تغيير آلية قنوات الاتصال المستخدمة بين الممارسين؟
7. In respect to misinterpretation of the information and design representations:
   i. What are the main reasons for the occurrence of misinterpretation of the information and design representations by using BIM between professionals? And how this related to communication channels used?
   ii. And how misinterpretation between different professionals impact on the mechanism used of communication channels ?

Appendix 2: Pilot study Interview questions

iii. How does the lack of interactive participants affect the project parties to use another alternative channels for seeking for information?

- ما هي الأسباب الرئيسية المسببه لسوء تفسير المعلومات و التشكيلات التصميمية بين مختلف المهنيين ؟ وعلاقتها بالقنوات الاتصالية المستخدمة؟
- وكيف اثر سوء الفهم بين المهنيين في احداث تغير في القنوات الاتصالية؟
- وكيف اثر وجود اعضاء فريق غير نشيطين في العملية الاتصالية على احداث تغير في سلوك اعضاء المشروع في البحث عن المعلومة باستخدام بدائل اخري للتواصل؟ كالأيميل للتوثيق؟

Theme 2: Collaborative Team

8. How is the diversity of skills and experiences between team members influenced in communication channels used?
   - كيف أثر اختلاف مهارة وخبرة بين أعضاء الفريق على قنوات الاتصال المستخدمه ؟

Theme 3: leadership

9. About leader role:
   i. What the role could team leader have played to strengthen the mutual trust between professionals; in aim to improve the information exchange process ?
   ii. And how subsequently mutual trust impact on the mechanism used for communication channels?
   - ما هو الدور الذي لعبه قائد الفريق نحو تقويه الثقة المتبادلة من اجل تحسين عملية تبادل المعلومات بين اعضاء الفريق ؟
   - وكيف بالتالي اثر تحسين الثقة المتبادلة لاحقا على آلية المستخدمة لقنوات الاتصال ؟
10. What are the possible types of support might your institutional provided to their members toward using new or alternative channels?
    - ما هي أنواع الدعم الممكنة التي توفرها المؤسسة لأعضائها لتحفيزهم نحو استخدام انواع جديدة او بدائل مختلفة في قنوات الاتصال؟

Appendix 3: Main Case Study Interview Questions

University of Reading

Interview Questions

1. نبذه مختصره عنك فيما يتعلق بالخبرة، والخلفية، وعدد المشايع التي تم تنفيذها بالبيم، والتخصص الدقيق.

1. Brief summary in relation to your experience, backgrounds, number of BIM projects have been implemented .

2. من خلال تجربتك، ما هو البيم ؟ وما هي الفلسفة وراء تطبيقها في المشاريع التصميميه؟

2. From your experience, what is BIM, and what is the philosophy behind implementing in the design process?

3. هل تعتقد أن البيم حسن من عمليه تبادل ومشاركه المعلومات بين الممارسين ؟ وكيف؟

3. Do you think that BIM has improved the process of information exchange and sharing among the professionals? And how?

4. ما هي القنوات الاتصالية التي تم استخدامها في المشاريع القائمه على البيم ؟ وعلى أي اساس تم الاختيار؟

4. What are the communication channels that were used in the BIM work environment? And on what basis it has been selected?

5. هل استخدام القنوات الاتصالية كانت بصوره ثابتة من حيث نوعها وعدد مرات استخدامها، او متغيرة؟ وما هي العوامل وراء هذا التغير؟

5. Do the using of the communication channels were fixed (static) in terms of the type and frequency of use, or variable? What are the factors behind this change?

6. مقارنه بين المشاريع المنفذه بالبيم وبدون البيم: هل قلل البيم من الحاجه الي التواصل اوبالعكس زاد؟ كيف؟ ولماذا؟

6. Comparison between projects implemented BIM and without BIM: Did BIM has reduced the need for communication or vice versa? How? And why ?

7. بجانب استخدام البيم، هل هناك برامج اخرى تعاونيه كانت استخدمت بالتزامن للتحكم وإدارة المشاريع، وهل اثرت من ناحية القنوات الاتصالية المستخدمة؟

7. Besides using BIM Are there other collaborative software were used simultaneously to control and manage the project, and are affected in terms of communication channels used?

8. هل هناك عوامل اخرى تريد اضافتها اثرت من خلال تجربتك في احداث تغير على القنوات الاتصالية غير التي تم ذكرها سابقا ؟ ما هي، وكيف اثرت؟

8. Are there other factors you want to add have influenced in making change on the communication channels other than those mentioned above? What is, and how it has affected?

The End of The Questions ……..……

Appendix 4: Information Sheet

Aljwhara A.Alnaser

scme@reading.ac.uk

A.A.A.Alnaser@pgr.reading.ac.uk

1/6/2015

BIM, and Communication Modes
Information Sheet

My name is **Aljwhara A. Alnaser** and I am a **PhD candidate** in the School of Construction Management and Engineering at the University of Reading.

I am carrying out a study on **to explore the implications of BIM execution on existing mechanism of communication modes used by various professionals in design process.** I am particularly interested in the way of which BIM make changes on communication modes used, and for this reason I would like to interview **professionals within design process in Saudis'** firms

If you are willing to be interviewed you will be asked to participate in an interview of about **how BIM impact communication modes.** During the interview I will ask you questions on **your experience with BIM, and how it make changes on communication modes**. You can choose "not to answer any questions/not to participate in any phase of the research" . You are free to withdraw from the study at any time.

At every stage, your identity will remain confidential. Your name and all identifying information will be removed from the written transcript. My supervisor and I will be the only people who will have access to this data. My supervisor is **Dr. Chris Harty** and can be contacted on **c.f.harty@reading.ac.uk.**

With your permission, I would like to "video record/tape the interview and transcribe sections later/take notes for analysis" . **DisplayText cannot span more than one line!**. The data will be kept securely and destroyed when the study has ended, which will be a maximum of 5years from completion of research. The data will be used for academic purposes only.

Copies of the completed dissertation will be available on request. If you have any further questions about the study, please feel free to contact me at the above address**.**

This project has been subject to ethical review, according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct.